Lummi Reservation Storm Water Management Program

Technical Background Document

December 1998

LUMMI RESERVATION STORM WATER MANAGEMENT PROGRAM

TECHNICAL BACKGROUND DOCUMENT

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LUMMI RESERVATION STORM WATER MANAGEMENT PROGRAM

EXECUTIVE SUMMARY

The goals of the Lummi Reservation Storm Water Management Program are to: 1) minimize the opportunities for storm water to wash pollutants into aquifer recharge zones and resource rich estuaries and tidelands of the Reservation, 2) minimize the downstream impacts of development on storm water quantity and quality, and 3) maximize the opportunities for infiltration and aquifer recharge. These goals are similar to and consistent with the Lummi Nation Wellhead Protection Program goals (LIBC 1997, LIBC 1998a).

The Lummi Nation finds that contamination of surface waters on the Reservation, tidelands and estuaries, wellhead areas, and ground water resources has a direct, serious, and substantial effect on the political integrity, economic security, and the health and welfare of the Lummi Nation, its members, and all persons present on the Reservation, and that those activities posing threats of such contamination, if left unregulated, also could cause such adverse impacts. Accordingly, the Lummi Natural Resources Department, in conjunction with the Lummi Planning Department, is developing a storm water management program for the Reservation based on the foregoing findings and the following considerations:

- With the exception of water discharged into Washington State aquatic lands from the two wastewater treatment plants, all water that falls onto or passes through the Lummi Reservation discharges to resource rich tidelands and/or estuaries of the Lummi Nation. These resources, which are culturally and economically important to the Lummi Nation and its members, surround the Reservation uplands. Tideland resources include salmon, shellfish, extensive eel grass beds, herring spawning grounds, surf smelt, sand lance, wildlife, and water supply intakes for a salmon and shellfish hatchery.
- The Lummi Nation goal is for waters of the Reservation to comply with the federal Clean Water Act as development occurs.
- Population projections, planned economic and institutional growth on the Reservation, and the small percentage of Reservation land that has been developed all suggest that portions of existing forested and agricultural lands will be converted to residential, commercial, or community uses in the coming years. Land use changes where forested or agricultural lands are converted to residential, commercial, or community uses can be expected to affect storm water quantity and quality.
- In general, development impacts vegetation and soil properties in a manner that results in greater storm water volumes, higher peak discharges, and lower water quality. Minimizing these adverse impacts from development and maximizing the protection of sensitive and important natural resources is necessary to protect the political integrity, economic security, and the health and welfare of the Lummi Nation, its members, and all persons present on the Reservation.

- As a finite resource, ground water is one of the most important and critical of the Lummi Nation's resources. Storm water is an important source of ground water recharge and a potentially significant source of ground water contamination.
- Over 95 percent of the residential water supply for the Reservation is pumped from local ground water wells; contamination of wellheads carries the risk of adversely affecting the health of persons drinking or using water from these supplies.
- The on-Reservation salmon hatchery program, which is culturally and economically significant to the Lummi Nation and its members, is dependent on ground water. No suitable alternative water sources exist on or near the Reservation for the salmon egg incubation program and salmon rearing operation.
- Ample supplies of ground water of good quality are essential to serve the purposes of the Reservation as the permanent homeland of the Lummi Nation and its members.
- Ground water resources are vulnerable to contamination by pollutants introduced on or near the ground surface by human activities. Agricultural, residential, community, commercial, and industrial land uses increase the potential for ground water contamination.
- Reservation ground water resources are particularly vulnerable to pollution due to geographic and hydrogeologic conditions, which may be exacerbated by future growth and development on the Reservation. The Reservation is located in a coastal area along the inland marine waters of the Puget Sound and Georgia Strait. Most of the existing water supply wells on the Reservation are located within a half mile of marine waters. Progressive salt water intrusion already has led to the closure of several of these public water supply wells. Increased pumping, possible future reductions in ground water recharge areas as the forested Reservation uplands are converted to residential and other uses, and rapid economic and population growth could further threaten the Lummi Nation's ground water resources if such activities are not managed effectively. Managing storm water to minimize water quality impacts of development and to maximize ground water recharge will help to protect the limited and vulnerable ground water resources on the Reservation.
- Ground water contamination could lead to the loss of the primary water supply source for the Reservation because water supply wells are difficult to replace, ground water contamination is very expensive to treat, and some damages to ground water caused by contamination may be impossible or unfeasible to mitigate.
- Alternative water sources to serve the needs of the Reservation are expensive and may not be available in amounts sufficient to replace existing supplies and to provide for future anticipated tribal economic and residential growth. Moreover, alternative water sources would require substantial amounts of funding for the infrastructure upgrades that would be necessary to import larger volumes of water onto the Reservation. Finally, alternative water sources may be subject to service interruptions over the long term due to natural or human generated disasters.

Vegetation removal and replacement with residential, commercial, or community land uses impacts storm water quantity and quality for a number of reasons including:

- The roots, leaves, and stems of vegetation provides surface roughness. This roughness reduces the speed that water can move overland and acts as a filter to trap sediment. The slower that water flows over a surface, the greater the opportunities for ground water recharge. The more water that infiltrates to the soil, the less water is available to flow overland as storm water runoff. Because less water is available for overland flow, the opportunities for erosion and sediment transport by water are also reduced.
- Vegetation provides a protective cover for soil which reduces erosion by absorbing the energy of rainfall.
- Vegetation provides organic matter to the soil and thereby increases its capacity to hold water.
- Plant roots hold soil particles in place and help to prevent soil loss.
- The area covered by impervious surfaces increases as forested and agricultural lands are converted to roads, houses, buildings, schools, and other related structures. Since precipitation cannot infiltrate impervious areas, ground water recharge opportunities are reduced and storm water runoff generally increases.
- Because of the higher percentage of impervious surfaces in developed areas, runoff can be expected to be of greater volume, have higher peak discharges, and have a shorter duration relative to the forested condition.
- Evapotranspiration from vegetation is analogous to a pump removing water from the soil and reintroducing it to the atmosphere. Evapotranspiration reduces the amount of water available for surface water runoff and ground water recharge. If evapotranspiration is reduced, surface water runoff generally increases.
- In some cases, ground water recharge can increase as a result of vegetation removal. However, increases in ground water recharge can be offset by the increased surface water runoff (which results in a decrease in the amount of water available for recharge) or increased ground water discharge due to higher hydraulic heads.

In addition to removing existing vegetation (land clearing), development is often associated with some level of earthmoving during construction phases and some level of impact on storm water quantity and quality once the development is in place. Common storm water related impacts of construction and development include:

- During clearing and construction activities, soil compaction occurs as heavy construction machinery runs over the land surface. Similar to an impervious surface, increased soil compaction reduces infiltration and ground water recharge which results in increased surface water runoff.
- Reworking and exposing soil during construction increases opportunities for erosion and sediment transport.
- There are numerous potential storm water pollutants associated with residential, commercial, and community land uses. These pollutants include: oils, metals, household chemicals, lawn and garden chemicals, street litter, and sediment.

Erosion and sediment control during construction is important because:

- Many pollutants adhere to the clay and other fine particles that comprise sediment. Transported sediment increases the potential for the off-site transport of pollutants and the subsequent degradation of water quality in the receiving waters (i.e., the estuaries and tidelands of the Reservation).
- Increases in the quantity of runoff can result in downstream erosion and property damage.
- Increased sediment from erosion can obstruct aquatic habitat and downstream storm water facilities (which will require increased maintenance).

To reduce the impacts of development on storm water and achieve the storm water management goals, appropriate best management practices (BMPs) must be effectively applied. Effective use of BMPs, coupled with land use zoning, is needed to minimize the impacts of development on storm water. Examples of using BMPs to reduce the impacts of development activities on storm water quantity and quality include:

- Planning development to fit the topography, soils, drainage patterns, and natural vegetation of the site.
- Conducting pollution prevention activities including public education and household hazardous waste collection and disposal events.
- Minimizing impervious areas (i.e., paved or compacted areas).
- Preserving wetland areas.
- Controlling erosion and sediment from disturbed areas within the project site or area.
- Minimizing the extent of disturbed areas.
- Conducting site disturbance work during the drier parts of the year (i.e., May through September).
- Stabilizing and protecting disturbed areas from runoff as soon as possible.
- Minimizing runoff velocities by minimizing slope length and gradient and protecting natural vegetative cover.
- Implementing a thorough storm water facilities monitoring and maintenance program.
- Constructing properly designed detention ponds, wetlands, infiltration trenches, grass swales, and filter strips.

Because storm water movement does not follow private property or political boundaries, and because community participation in developing and implementing the management plan is necessary for a successful program, community involvement is a key element of the Lummi Reservation Storm Water Management Program. The two elements of the community involvement plan are 1) public education and, 2) interjurisdictional coordination and cooperation for activities off-Reservation that affect on-Reservation resources.

The community involvement plan, which will be part of a storm water management ordinance development effort, will be implemented in the coming months. Because of similarities between the programs, the community involvement effort of the storm water management program will be implemented in conjunction with the community involvement effort of the Lummi Wellhead Protection Program (LIBC 1997, LIBC 1998a).

Ordinances for both the storm water management program and the wellhead protection program will form two new chapters in the Lummi Water code (administered by the Lummi Natural Resources Department). Both the storm water management and the wellhead protection ordinances are scheduled to be drafted by March 1999, have public hearings during 1999, and be adopted during early 2000.

Funding for the technical background documents that form the basis of the Lummi Reservation Storm Water Management Program and the Lummi Nation Wellhead Protection Program was provided by the U.S. Bureau of Reclamation. Funding for the ordinance development phases of the Lummi storm water management and wellhead protection programs has been provided by the U.S. Environmental Protection Agency (EPA) as part of the General Assistance Program (GAP).

1. INTRODUCTION

The goals of the Lummi Reservation Storm Water Management Program are to: 1) minimize the opportunities for storm water to wash pollutants into aquifer recharge zones and resource rich estuaries and tidelands of the Reservation, 2) minimize the downstream impacts of development on storm water quantity and quality, and 3) maximize the opportunities for infiltration and aquifer recharge. These goals are similar to and consistent with the Lummi Nation Wellhead Protection Program goals (LIBC 1997, LIBC 1998a).

The Lummi Nation finds that contamination of surface waters on the Reservation, tidelands and estuaries, wellhead areas, and ground water resources has a direct, serious, and substantial effect on the political integrity, economic security, and the health and welfare of the Lummi Nation, its members, and all persons present on the Reservation, and that those activities posing threats of such contamination, if left unregulated, also could cause such adverse impacts. Accordingly, the Lummi Natural Resources Department, in conjunction with the Lummi Planning Department, is developing a storm water management program for the Reservation based on the foregoing findings and the following considerations:

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- As a finite resource, ground water is one of the most important and critical of the Lummi Nation's resources. Storm water is an important source of ground water recharge and a potentially significant source of ground water contamination.

- Over 95 percent of the residential water supply for the Reservation is pumped from local ground water wells; contamination of wellheads carries the risk of adversely affecting the health of persons drinking or using water from these supplies.
- The on-Reservation salmon hatchery program, which is culturally and economically significant to the Lummi Nation and its members, is dependent on ground water. No suitable alternative water sources exist on or near the Reservation for the salmon egg incubation program and salmon rearing operation.
- Ample supplies of ground water of good quality are essential to serve the purposes of the Reservation as the permanent homeland of the Lummi Nation and its members.
- Ground water resources are vulnerable to contamination by pollutants introduced on or near the ground surface by human activities. Agricultural, residential, community, commercial, and industrial land uses increase the potential for ground water contamination.
- Reservation ground water resources are particularly vulnerable to pollution due to geographic and hydrogeologic conditions, which may be exacerbated by future growth and development on the Reservation. The Reservation is located in a coastal area along the inland marine waters of the Puget Sound and Georgia Strait. Most of the existing water supply wells on the Reservation are located within a half mile of marine waters. Progressive salt water intrusion already has led to the closure of several of these public water supply wells. Increased pumping, possible future reductions in ground water recharge areas as the forested Reservation uplands are converted to residential and other uses, and rapid economic and population growth could further threaten the Lummi Nation's ground water resources if such activities are not managed effectively. Managing storm water to minimize water quality impacts of development and to maximize ground water recharge will help to protect the limited and vulnerable ground water resources on the Reservation.
- Ground water contamination could lead to the loss of the primary water supply source for the Reservation because water supply wells are difficult to replace, ground water contamination is very expensive to treat, and some damages to ground water caused by contamination may be impossible or unfeasible to mitigate.
- Alternative water sources to serve the needs of the Reservation are expensive and may not be available in amounts sufficient to replace existing supplies and to provide for future anticipated tribal economic and residential growth. Moreover, alternative water sources would require substantial amounts of funding for the infrastructure upgrades that would be necessary to import larger volumes of water onto the Reservation. Finally, alternative water sources may be subject to service interruptions over the long term due to natural or human generated disasters.

Pursuant to 40 CFR 122.26 (b) (13), storm water is defined as runoff from a storm, snow melt runoff, and surface runoff and drainage. The purpose of the Lummi Reservation Storm Water Management Program is to:

1. Describe the occurrence of storm water on the Lummi Reservation;
2. Discuss how land use changes affect storm water quantity and quality;
3. Identify potential sources of storm water contamination in the watersheds that drain to the adjacent waterways and aquifer recharge zones of the Reservation;
4. Identify the best management practices (BMPs) available to achieve the storm water management goals;
5. Describe the public involvement plan for the Lummi Storm Water Management Program; and
6. Present the 1998 - 2000 action plan for the program.

Effective use of BMPs, coupled with land use zoning, is needed to minimize the impacts of development on storm water. This background document is intended to serve as the technical basis for a community involvement effort and the eventual development of a Lummi Reservation Storm Water Management Ordinance. The community involvement plan will be implemented in the coming months as the ordinance is drafted; the storm water ordinance development effort is underway and should be completed in early 2000.

This storm water technical background document is based on a field inventory of storm water facilities on the Lummi Reservation (LWRD 1997), literature reviews on the impacts of land use changes on storm water quantity and quality, and a literature review on storm water best management practices (BMPs).

This plan is organized into the following nine sections:
- Section 1 is this introductory section.
- In Section 2, the physical characteristics of the study area are described.
- In Section 3, an inventory of storm water facilities on the Lummi Reservation is presented and the occurrence of storm water on the Reservation described.
- In Section 4, potential impacts of land use changes on storm water quantity and quality are described and an inventory of potential sources of storm water contamination is presented
- In Section 5, a literature review on BMPs for storm water is presented.
- In Section 6, the community involvement plan is presented.
- In Section 7, the 1998 - 2000 action plan for the Lummi Reservation Storm Water Management Program is described.
- In Section 8, the storm water management program is summarized.
- References used in the program development are presented in Section 9.

2. STUDY AREA DESCRIPTION

To effectively manage storm water on the Reservation, the factors that control its occurrence, movement, quantity, and quality must be known. In this section, the topography, watersheds, climate, hydrogeology, soils, land use, surface water resources, and storm water runoff on the Lummi Reservation are described.

2.1 TOPOGRAPHY

The Lummi Reservation has two relatively large upland areas and a smaller upland area on Portage Island (Figure 2.1). The maximum elevation of the northern upland area is about 220 feet above mean sea level (ft msl). The southern upland area is the Lummi Peninsula with a maximum elevation of about 180 ft msl. The maximum elevation on Portage Island is about 200 ft msl. The flood plains of the Lummi and Nooksack rivers, with an average elevation of approximately 10 ft msl, lie between the northern and southern upland areas. The Nooksack River flood plain and the Nooksack River delta are located along the northeastern extent of the Lummi Peninsula upland. The upland areas of the Reservation amount to about 12,500 acres; the Reservation tidelands total around 8,000 acres.

The two relatively large upland areas are drained by short, intermittent streams and numerous springs both above and below the line of ordinary high water. These streams and springs discharge onto tribal tidelands along either Bellingham Bay, Hale Passage, Lummi Bay, Onion Bay, Georgia Strait, or to the flood plain of the Lummi and Nooksack rivers. The flood plain is drained by a network of agricultural drainage ditches and the Lummi and Nooksack rivers. The drainage on Portage Island consists of at least two intermittent streams that drain northward to Portage Bay. Springs along the upland areas of Portage Island and below the line of ordinary high water also discharge to marine waters and Reservation tidelands.

2.2 RESERVATION WATERSHEDS

A watershed is a land area defined by topography that is drained by a stream system. Watershed boundaries are generally delineated using U.S. Geological Survey (USGS) topographic maps and, starting from a point on the stream system that is defined by the geology and topography as the watershed outlet, following the ridgelines shown by the contour lines. This method is commonly used in upland watersheds where the contour lines are relatively closely spaced and a single watershed outlet is apparent. In lowland areas with relatively flat topography, identifying the watershed outlet and associated boundaries is more difficult. Often in lowland or coastal areas there is not a single location or point that can be identified from the topography, geology, and/or hydrography as a watershed outlet.

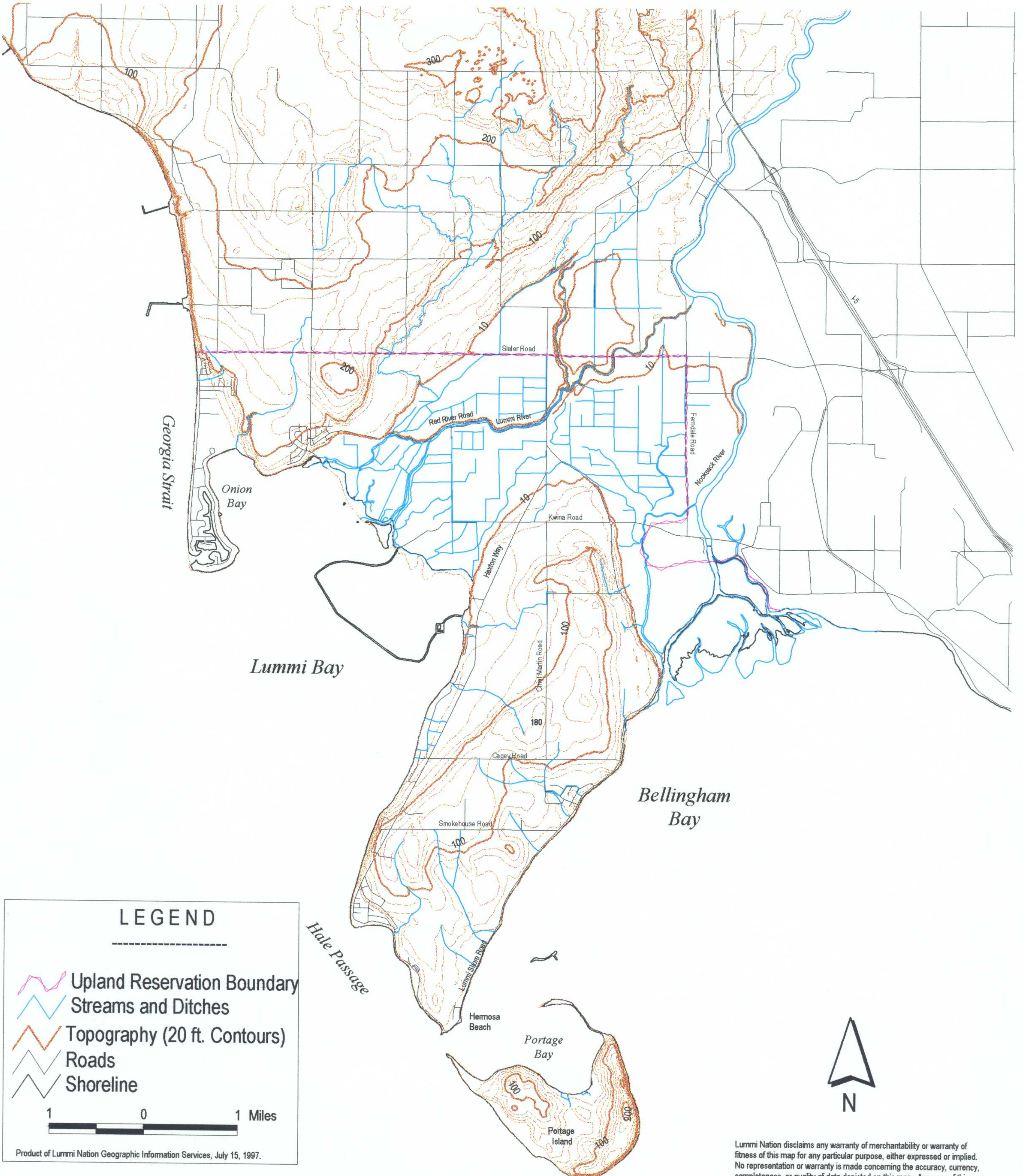

Figure 2.1 Lummi Reservation Topography

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The four 1:24,000 scale USGS 7.5-minute quadrangle maps that include the Lummi Reservation were used as base maps to identify the boundaries of the Reservation watersheds. These maps have 20-foot contour intervals. Aerial photographs and field observations during the storm water facilities inventory (LWRD 1997) were used to identify the approximate locations of agricultural drainage ditches, roadside drainage ditches, and unmapped intermittent streams on the Reservation. Field observations made during the storm water facilities inventory were also used to determine the directions of surface water flow and to refine preliminary delineations of the watershed boundaries.

The storm water facilities inventory identified 48 culverts along upland roadways that discharged directly to either tribal tidelands/marine waters or to the flood plains of the Lummi and Nooksack rivers. Although subdividing the Reservation uplands by delineating the contributing areas to these 48 culverts was considered as an approach to managing storm water, an alternative approach that involved combining drainage areas of topographically adjacent culverts was adopted. This alternative approach was used both to reduce the number of watersheds and to accurately reflect the incomplete knowledge on the exact locations of watershed divides in the relatively flat terrain.

The five-step approach used to delineate watersheds on the Reservation was the following:

1. Initially, generalized watershed boundaries were delineated from the 1:24,000 scale USGS topographic maps.
    - A total of 19 watersheds were identified on the Reservation.
    - Seven of the identified watersheds extend beyond the Reservation boundaries;
    - The remaining 12 watersheds are located within the exterior boundaries of the Reservation.
    - Of the seven watersheds that extend beyond the Reservation boundaries, one is the Nooksack River watershed.
    - The Nooksack River watershed had been previously delineated by the USGS and others (WSDC 1960) and was not delineated as part of this effort.
2. A storm water facilities inventory was conducted to identify the locations of culverts, bridges, tide gates, catch basins, roadside ditches, and agricultural ditches on the Reservation (LWRD 1997).
3. Intermittent streams that were not shown on the USGS maps were identified during the field inventory and their approximate locations mapped.
4. The flow direction(s) in the identified ditches and channels were identified by field observations made during the storm water facilities inventory and other related studies.
    - Descriptions of the flow paths were entered into a storm water facilities database that is linked to a geographic information system (GIS).
    - The flow direction(s) in the ditches and channels in the flood plain were determined for both high and low tidal conditions.
5. The locations of the generalized watershed boundaries identified from the topographic maps were refined as necessary to be consistent with field observations of topography and flow directions.

Figure 2.2 is the working map for the location of the hydrography, watershed boundaries, transportation corridors, and topography of the Reservation. It is anticipated that this working map will be refined as part of the public involvement process and as better location and topographic information becomes available. Similarly, the results of a comprehensive wetland inventory on the Reservation, which is scheduled to occur during the spring of 1999, will also be incorporated in an updated Figure 2.2.

The Reservation watersheds were identified by alphabetic letters (A through S) on an interim basis. It is anticipated that names will be assigned to the watersheds over time. The 19 watersheds and the assigned identification letters are shown in Figure 2.2. The individual watersheds and associated storm water drainage networks are described along with the storm water facilities inventory in Section 3 of this technical background document. In Section 4, potential storm water contaminant sources in each watershed are identified.

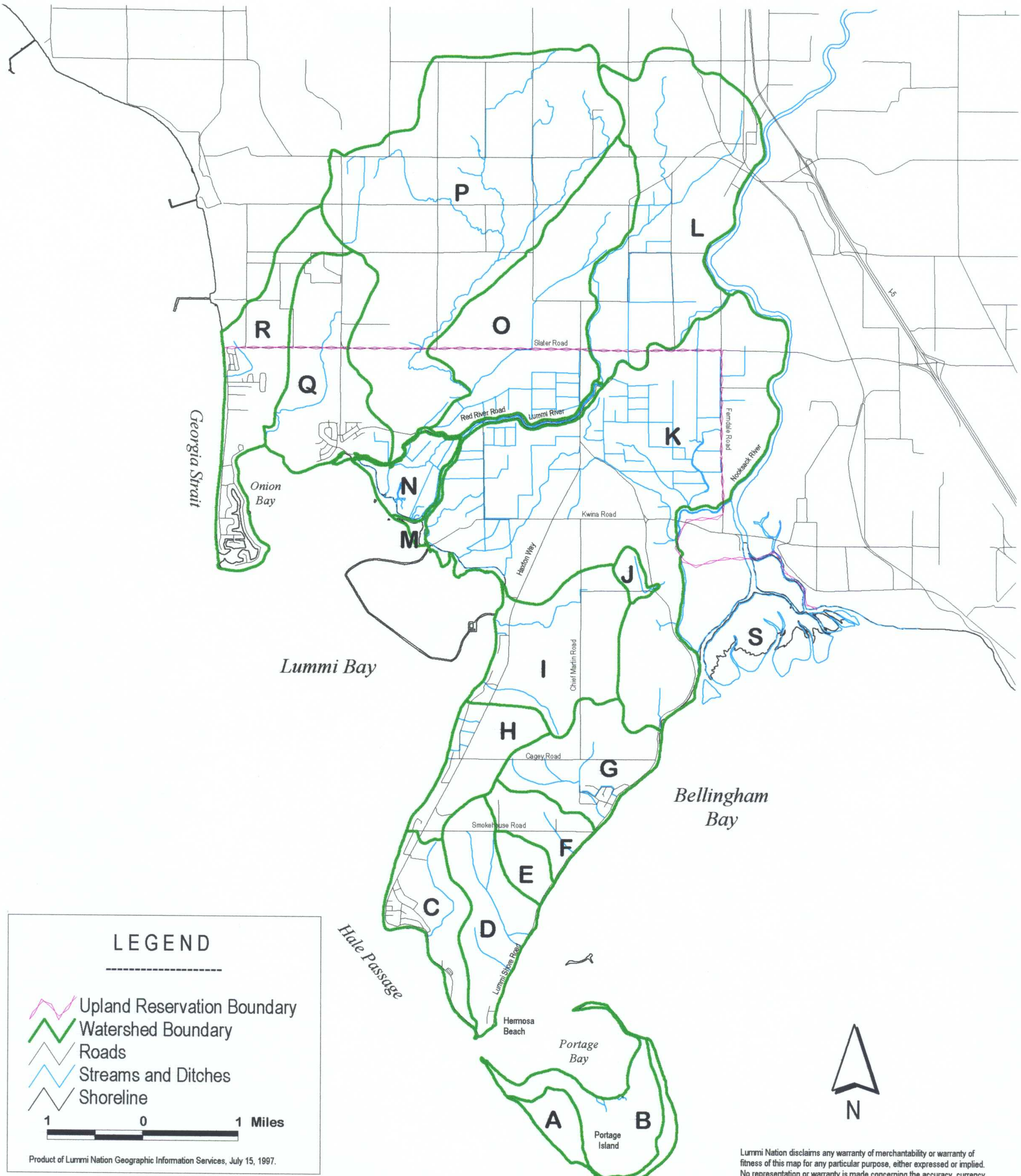

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Figure 2.2 Lummi Reservation Watersheds

2.3 CLIMATE

Based on climate data collected at the Bellingham Airport, the average annual precipitation on the Reservation over the 1960-1990 “normal” period is approximately 36.2 inches. On average, November, December, and January are the wettest months; June, July, and August are the driest months. About 75 percent of the average annual precipitation occurs from October through April; the remaining 25 percent occurs from May through September.

Factors such as surface cover, drainage area, time between storms, rainfall intensity, and precipitation duration affect the quantity and quality of storm water runoff from a watershed. The “return period” is an expression of the likelihood that a particular sized storm will occur during any year. The probability or chance that a storm with a 2-year return period will occur during any given year is 50 percent. Similarly, there is a 1 percent chance that a “100-year storm” will occur during any year. The precipitation quantities over a 24-hour interval for storms with return periods of 2-, 10-, 25-, and 100-years on the Lummi Reservation are tabulated in Table 2.1.

Table 2.1 24-Hour Precipitation Totals for the Lummi Reservation[1]

Return Period (Years)	Probability Of Occurrence During Any Year (Percent)	Precipitation Amount (Inches)
2	50	1.8
10	10	2.5
25	4	2.9
100	1	3.6

[1] NOAA, 1978

The water quality design storm for the Puget Sound basin is identified as the 6-month, 24-hour rainfall event (Ecology 1992). The water quality design storm is used when the storm water management requirement is only to remove pollutants and not to also control peak runoff discharge. For the Puget Sound basin, the water quality design storm can be estimated as 0.64 times the 2-year, 24-hour storm (Ecology 1992). Using this criteria for the Lummi Reservation, the water quality design storm would be 1.15 inches of rain in 24 hours.

The rainfall intensity (inches per hour) over the Reservation for return periods of 5-, 10-, 25-, 50-, and 100-years for durations of 30-, 60-, and 90-minutes are shown in Table 2.2.

Table 2.2 Rainfall intensity, duration, and frequency for the Lummi Reservation[1]

	Duration: 30 min.	Duration: 60 min.	Duration 90 min.
Return Period (years)	Rainfall Intensity (in/hr)	Rainfall Intensity (in/hr)	Rainfall Intensity (in/hr)
5	0.80	0.58	0.47
10	0.90	0.66	0.52
25	1.90	0.78	0.63
50	1.24	0.88	0.70
100	1.40	0.97	0.78

[1] Data Source: Washington Department of Transportation

Temperature data collected at the Bellingham Airport over the 1960-1990 period indicate that the warmest months are July and August. During these months the average maximum daily temperature is approximately 71 degrees Fahrenheit (°F). December and January are the coldest months. During December and January the average minimum daily temperature is about 32°F. May through September is the approximate growing season for agricultural crops in the area (Gillies 1998).

Evapotranspiration has not been measured on the Reservation but has been estimated. Phillips (1966) estimated the average annual actual evapotranspiration for a 6-inch water holding capacity soil at the Marietta 3 NNW station to be approximately 18.8 inches. This estimate represents about 52 percent of the mean annual precipitation. A review of evapotranspiration estimates from 27 studies conducted in the Puget Sound Lowland (Bauer and Mastin 1997) suggest an average evapotranspiration rate of around 17.3 inches. On average, the estimated mean annual evapotranspiration from the 27 studies compiled by Bauer and Mastin (1997) was about 46 percent of the mean annual precipitation.

Wind data for Bellingham indicates that the prevailing wind direction on the Reservation is from the south and southeast with gusts upward of 80 miles per hour. Winds from the west are not as common and generally not as strong (U.S. Army Corps of Engineers 1997). A wind rose developed from meteorological data collected at the north boundary of the Tosco oil refinery over the August 1982 through March 1984 period (Mobil Oil Corporation 1986) indicated that the wind direction is from the north or northwest about 6 percent of the time. This wind rose, which is north of the Reservation and near Georgia Strait, indicates that the wind direction is from the northeast about 20 percent of the time.

Because most of the precipitation occurs during the winter months when evapotranspiration demand is low, most of the ground water recharge and storm water runoff occurs during this season. After the rainy season and during the summer months when evapotranspiration demand is high and vegetation slows the movement of storm water, the amount of water available for ground water recharge or surface water runoff is small. Despite the lush summer vegetation, infrequent cloud bursts and the relatively impervious soils common to the Reservation can combine to produce storm water runoff during the summer months. Because of the accumulation of debris between the infrequent summer storms, resultant pollutant loading in storm water can be higher during the summer months relative to the rainy season runoff.

2.4 HYDROGEOLOGY

The hydrogeologic conditions on the Lummi Reservation have been described previously by the USGS and others (Washburn 1957, Cline 1974, Easterbrook 1973, Easterbrook 1976). In general, the Reservation is underlain by unconsolidated sediments deposited as glacial outwash, glaciomarine drift, glacial till, and flood plain or delta deposits of Quaternary age (Washburn 1957). The unconsolidated deposits consist of clay, silt, sand, gravel, and boulders. Because the composition of the deposits commonly change laterally over short distances, it is difficult to distinguish between the different stratigraphic units from existing well log data.

2.4.1 Geology

The sediment units that occur on the Reservation, as described by Cline (1974) and Easterbrook (1976) in order from youngest to oldest, are summarized below.

- **Alluvium:** The alluvium is derived from sediment carried by the Lummi and Nooksack rivers and deposited on the flood plain. It is comprised mostly of clay, silt, sand, and some gravel.
- **Beach Deposits:** The beach deposits are laid down by littoral drift processes. The deposits are mostly sand with some locally abundant gravel and occur mainly at the western part of the Reservation from Neptune Beach to Sandy Point and at Gooseberry Point.
- **Older Alluvium:** The older alluvium was deposited by the Lummi and Nooksack rivers when the valley floor was relatively higher than at present. The unit consists mostly of fine sand with some silt and clay located on stream terraces flanking the uplands above the flood plain. These deposits occur along the southeast flank of the Mountain View Upland and along the northeast flank of the Lummi Peninsula.
- **Gravel:** A thin unsaturated gravel unit is exposed at the surface at several locations on the Reservation. The unit consists of gravel and sand/gravel. In places, this unit appears to have been reworked by beach processes during post-glacial uplift and overlies glaciomarine drift. In other places, this unsaturated unit appears to overlie or be a part of the Esperance Sand unit (see below) and cannot be distinguished from the lower unit in the well records.
- **Glaciomarine Drift:** The Glaciomarine Drift unit was deposited late in the Fraser Glaciation (from about 20,000 years ago to about 10,000 years ago [Easterbrook 1973]). The drift is comprised of unsorted clay, silt, sand, gravel, and some cobbles and boulders. The deposits include both Kulshan and Bellingham drifts and generally yield little water. Limited sand and gravel lenses may contain small amounts of perched ground water.
- **Glacial Till:** The glacial till from the Vashon Stade of the Fraser Glaciation is comprised of poorly sorted clay, silt, sand, gravel, and some cobbles and boulders. The till deposits generally yield little or no water as till has a compact and concrete-

like texture. Because the presence of till is noted in only a few well logs and visible at only a few beach exposures, the occurrence of till on the Reservation is believed to be limited.

- **Esperance Sand:** The Esperance Sand unit (Easterbrook 1976), formerly named Mountain View Sand and Gravel, is comprised of stratified beds of sand and gravel with stratified lenses of sand. The unit overlies the Cherry Point Silt unit and underlies the glaciomarine drift and till; it is the major water yielding unit beneath the Reservation.
- **Cherry Point Silt:** The Cherry Point Silt unit is believed to be the oldest known unconsolidated stratigraphic unit in the northern Puget Sound lowland. This unit is comprised of a thick sequence of blue to brownish gray stratified clay and silt with minor sandy beds.
- **Bedrock:** Bedrock underlying the Reservation consists mostly of sedimentary rocks such as sandstone, siltstone, shale, and conglomerate. The bedrock does not occur at the surface and is deeply buried by the unconsolidated glacial deposits.

2.4.2 Reservation Aquifers

As noted above, ground water is obtained primarily from sand and gravel outwash deposits in the unconsolidated sediments (i.e., Esperance Sand unit). Glaciomarine drift is at or near the ground surface over much of the upland areas on the Reservation. The glaciomarine drift contains substantial amounts of clay which restricts the recharge to the underlying aquifer and promotes storm water runoff.

Two apparently separate potable ground water systems occur on the Lummi Reservation. One system is located in the northern upland area. This northern system appears to flow onto the Reservation from the north and drains to the west, south, and east. The second potable ground water system is located in the southern upland areas of the Reservation and is completely contained within the Reservation boundaries. The flood plains of the Lummi and Nooksack rivers, which contain a surface aquifer that is saline (Cline 1974), separate the two potable water systems. A third potable water system may exist on Portage Island, but information on water quality and the potential yield of this system is limited and inconclusive.

In general, both the northern and southern ground water systems contain two aquifer types (Washburn 1957, Easterbrook 1976). The upper aquifer type is comprised primarily of lenses of sand or sand and gravel in the glaciomarine drift. These relatively permeable lenses are not continuous throughout the area. The lower aquifer layer is comprised of advance outwash sand and gravel. The thickness of the lower aquifer, which appears to be semi-confined in places and unconfined in other places, is not known. The pebbly clay in the drift sediments and scattered deposits of till greatly slow the downward percolation of water to the lower aquifer and may act as a confining layer.

Because the hydrogeologic conditions on the Reservation vary considerably over short distances, the locations of the aquifer recharge zones are not definitively known at this time. It is likely that aquifer recharge areas are distributed over the upland areas.

However, given the high runoff potential of the glaciomarine drift that covers much of the Reservation upland, it is also possible that aquifer recharge areas are of limited areal extent and located primarily in only a few locations around the Reservation. Until more precise information is developed, all of the northern and southern upland areas on the Reservation are assumed to be aquifer recharge zones.

2.5 SOILS

The USDA-Natural Resources Conservation Service (NRCS) identified and described 40 different soil types on the Lummi Reservation (USDA 1992). As part of the characterization, each soil type was assigned to one of four hydrologic soil groups based on their runoff-producing characteristics. As shown in Section 4 of this plan, the hydrologic soil group, along with the cover type, drainage area, channel length, and land slope, can be used in the USDA Curve Number Method (USDA 1970) to estimate runoff volumes and hydrographs for specified storms (i.e., design storms).

The primary consideration in assigning a soil to a hydrologic soil group is the inherent infiltration capacity of the soil with no vegetation (USDA 1992). The hydrologic soil groups, which are labeled A, B, C, or D, are described in Table 2.3. In essence, Group A soils have a low runoff potential and a high infiltration potential whereas Group D soils have a high runoff potential and a low infiltration potential. Group B and Group C soils have runoff and infiltration potentials between Group A and Group D.

As shown in Table 2.3, about 13 percent of the soils on the Reservation have a low or moderately low runoff potential (Group A or Group B). The remaining 87 percent of the soils on the Reservation have a moderately high or high runoff potential (Group C or Group D). These soil characteristics suggest that less than 15 percent of the Reservation uplands have a good aquifer recharge potential.

As shown in Figure 2.3, the Group A and B soils are generally found along some of the tideland areas and the glacial outwash terraces of the Reservation. These soils are concentrated along Haxton Way south of Balch Road, along Lummi View Road near the Stommish Grounds, on Portage Island, and near Fish Point. There is an isolated area of Group B soils along the west side of Chief Martin Road near the abandoned landfill. The Group C and D soils are found along the glaciomarine drift plains in the upland areas and the flood plains of the Lummi and Nooksack rivers. Most of the northern and southern upland areas on the Reservation have a moderately high or high runoff potential. The soils north of the Reservation have been mapped by the NRCS but have not yet been incorporated into the geographic information system (GIS) maintained by the Lummi Nation. A review of the soil map units in the areas north of the Reservation suggests that most of these soils also have a moderately high or high runoff potential.

Table 2.3 Descriptions of Hydrologic Soils Groups on the Lummi Reservation

Hydrologic Soil Group	Description[1]	Percent of Reservation Soils

A	Soils having high infiltration rates even when thoroughly wetted, consisting chiefly of deep (3-6+ ft) well to excessively drained sands (loamy sands, sandy loam, and sands) and/or gravel. These soils have a high rate of water transmission and a low runoff potential.	2.7
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep (20+ inches) and moderately well to well drained soils with moderately fine to moderately coarse textures (loam, silt loam). These soils have a moderate rate of water transmission and a moderately low runoff potential.	10.0
C	Soils having slow infiltration rates when thoroughly wetted consisting chiefly of 1) soils with a layer that impedes the downward movement of water, and 2) soils with moderately fine to fine texture (sandy clay loam) and a slow infiltration rate. These soils have a slow rate of water transmission and a moderately high runoff potential.	40.4
D	Soils having very slow infiltration rates when thoroughly wetted consisting chiefly of 1) clay soils with a high swelling potential, 2) soils with a high permanent water table, 3) soils with clay pan or clay layer at or near the surface, and 4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission and a high runoff potential.	46.9

[1] USDA 1970

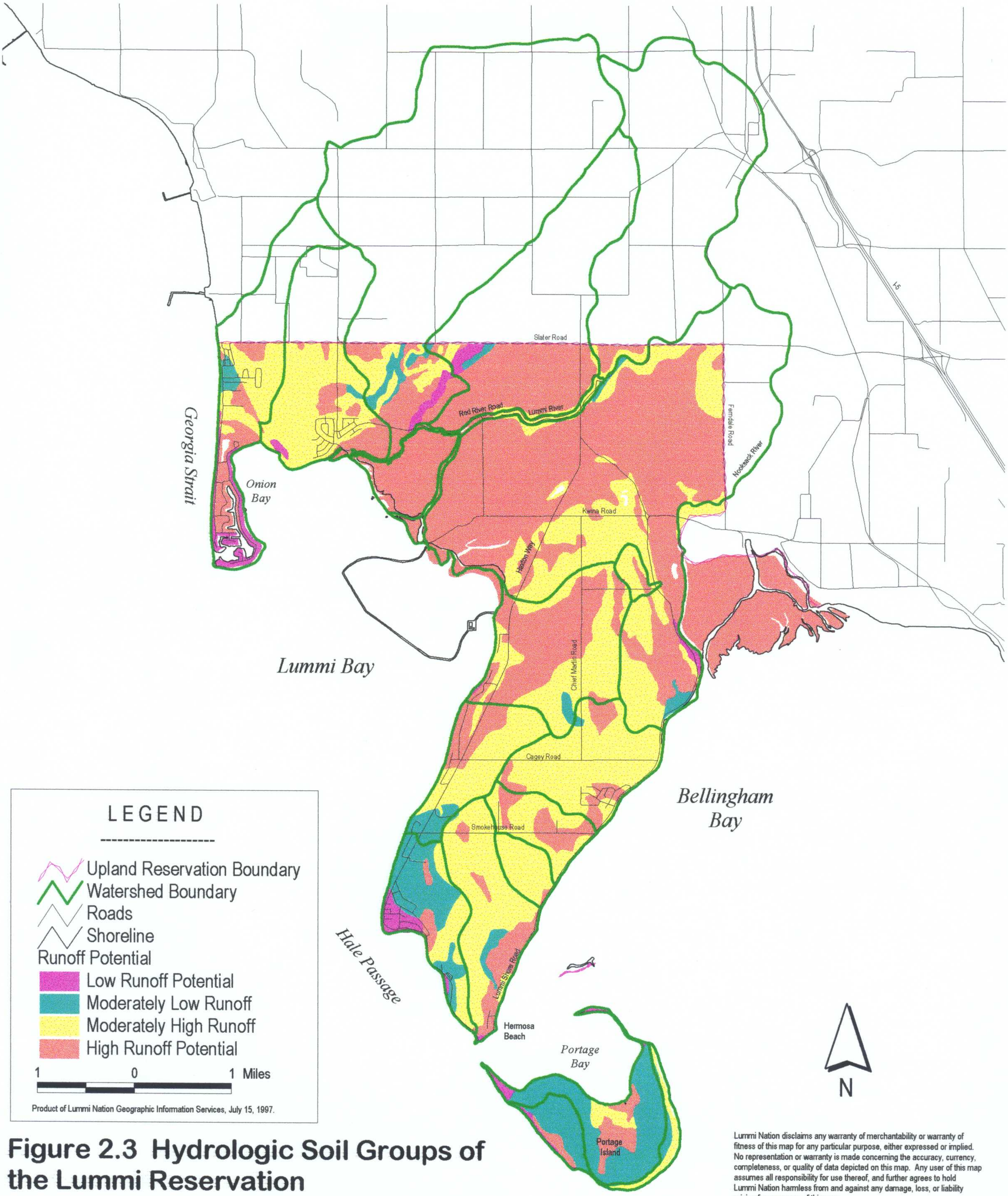

Figure 2.3 Hydrologic Soil Groups of the Lummi Reservation

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2.6 LAND USE

Like most places, land use changes on the Reservation have generally been associated with changes in vegetation types, decreases in the areas covered by vegetation, changes in natural drainage patterns, and increases in impervious surfaces. With the arrival of Euro-americans, forested land was logged, cleared, and drained for agricultural development, buildings, and eventually parking lots and other paved surfaces. Roads were cut through slopes and low spots filled. Many of these low spots were wetland areas. Natural drainage patterns on the Reservation were substantially altered by the road system and agricultural drainage and diking.

Historic, current, and projected future land uses on the Reservation watersheds are described below. Much of the information about historic land uses comes from the *Lummi Nation Comprehensive Environmental Land Use Plan: Background Document* (LIBC 1996).

2.6.1 Historic Land Use

Prior to the arrival of Euro-americans, the Lummi people were a fishing, hunting, and gathering society. Based on the accounts of Lummi Elders, early European explorers, and early photographs of the region, before 1850 the Lummi Reservation was dominated by old growth forests of massive Douglas fir, western hemlock, spruce, and western red cedar. Deciduous trees such as western big leaf maple, black cottonwood, red alder, and western paper birch were also likely present along the rivers, streams, and open areas. Understory vegetation probably included vine maple, Oregon grape, several different willows, ocean spray, salmon berry, thimbleberry, soapberry, and many others. Wetlands, streams, and rivers supported a unique array of plants adapted to wet environments. The marine shoreline was also a unique environment where only plants adapted to a saltwater influenced environment thrived.

The dominate forces that shaped vegetation patterns in the northwest prior to the arrival of Euro-americans were fires, wind storms, ice storms, floods, and traditional use of natural vegetation by the indigenous peoples. Native American uses of vegetation included the gathering of medicinal plants, use of willows and other shrubs for fishing, and extensive use of the western red cedar tree for many things including clothing, baskets, buildings, and canoes. Many plants were also used as food to complement the traditional diet of fish, shellfish, elk, and deer. Some of these foods, such as ferns, camas, and wapato, were cultivated in natural prairies along the Nooksack River.

Like most areas in the Nooksack River watershed downstream from Lynden, conversion of forest land to agricultural land occurred on the Lummi Reservation following the arrival of Euro-americans. In 1896 there were reported to be approximately 1,222 acres under cultivation on the Reservation. Along with clearing the forested land for agriculture, the landscape was ditched, wetland areas were drained, log jams were cleared, the Nooksack River was diverted to drain into Bellingham Bay, and the Lummi River delta cut off from the Nooksack River by a dike. All of these changes in the natural hydrology of the Lummi Reservation changed the distribution and patterns of wetland and riparian associated plant communities. The extent of the agricultural and roadside drainage network on the Reservation is shown in Figure 2.2.

One or more large fires swept through the Lummi Reservation sometime between 1850 and 1900. The cause of these fires is not definitively known, but they may have been started to fight the smallpox epidemics that struck the Lummi shortly after the settlers arrived. These fires destroyed nearly all of the remaining old growth forests.

Logging of timber on the Lummi Reservation began after the fires. Much of the cedar was cut into shingle bolts and shipped to local shingle mills. The old growth trees on Portage Island were cut down to fuel steamboats on the Nooksack River. Reforestation was not practiced during the early logging period and pioneer tree species such as alder, willows, and cottonwoods soon replaced the conifer forests and dominated the landscape. Although there are cedar groves and Douglas fir plantations, the present day forests on the Reservation are largely comprised of deciduous trees.

2.6.2 Current Land Use

As part of this study, a LANDSAT satellite image from August 15, 1991 was used to estimate the extent of various land uses in the watersheds that drain to the Reservation tidelands. The image had been classified into different land cover types by the Whatcom County Planning and Development Services. The land uses in the Nooksack River basin were characterized based on information presented in the Whatcom County Comprehensive Plan (Whatcom County 1997).

The focus of the LANDSAT image classification effort by Whatcom County was to analyze forest cover types and structure in the foothills of Whatcom County. Urban and agricultural classifications were not field validated to the extent of the forest cover types. Consequently, classification errors for these two cover types are apparent in the map of land cover types shown in Figure 2.4. For example, locations known to be agricultural fields were sometimes classified as urban/residential areas. Locations that had been mistakenly classified as urban/residential/industrial were generally attributed to grasses/agriculture land use except for Portage Island. On Portage Island, this classification was interpreted to be rocks on the beach areas.

In addition, wetland areas were not a separate land cover classification in the satellite image. The initial land cover types estimated from the LANDSAT image were refined based on existing GIS coverages of wetland locations. The GIS coverages of wetland locations were derived from the National Wetland Inventory maps (USFWS 1987) and from wetland location maps developed by a tribal consultant (Arnett 1994). When the wetland locations were overlaid on the classified land cover type GIS data layer, it was observed that the wetland areas generally corresponded to areas classified in the satellite image as either: coniferous and mixed forest, deciduous forest, or grasses/agriculture. To account for the wetland areas, the wetland area in each watershed as determined from the wetland location map was divided by three and the resulting surface area subtracted from the estimated area in each of these three cover classes.

The estimated distribution of land cover types/land uses on the Lummi Reservation is shown in Table 2.4 and the locations of the various land cover types are shown in Figure 2.4. As evident in Table 2.4, excluding both tribal tidelands and land cover/land use types in the Nooksack River watershed, approximately 91 percent of the Reservation watersheds are either agricultural, forested, or wetlands.

Table 2.4 Current land cover types/land uses of Lummi Reservation Watersheds[1]

Land Cover/Land Use	Percent of Area[1]
Grasses/Agricultural	51.55
Deciduous Forest	25.13
Wetlands	9.79
Coniferous and Mixed Forest	4.60
Scrub-Shrub	2.87
Residential/Urban/Industrial	2.75
Fallow Fields/Exposed Soil	2.07
Water	1.20
Rock	0.04

[1] Does not include the Nooksack River watershed or tribal tidelands

Based on estimates of land cover in Whatcom County (Whatcom County 1997), land cover/land use in the Nooksack River watershed is dominated by forested areas upstream from the town of Deming and agricultural lands downstream from Deming. Population centers such as Ferndale, Lynden, Everson, and Deming are located adjacent to the Nooksack River.

2.6.3 Future Land Use

The Lummi Planning Department used demographic profile data from the 1990 Census and projected that between 3,800 and 4,350 housing units will be needed on the Reservation by the year 2010 (LIBC 1996). These population projections, planned economic and institutional growth on the Reservation, and the small percentage of tribal land that has been developed suggest that portions of existing forested lands on the Reservation will be converted to residential and commercial uses in the coming years.

Similarly, the future land use in the Nooksack River watershed is projected to include more residential, commercial, and urban development to accommodate projected population increases (Whatcom County 1997).

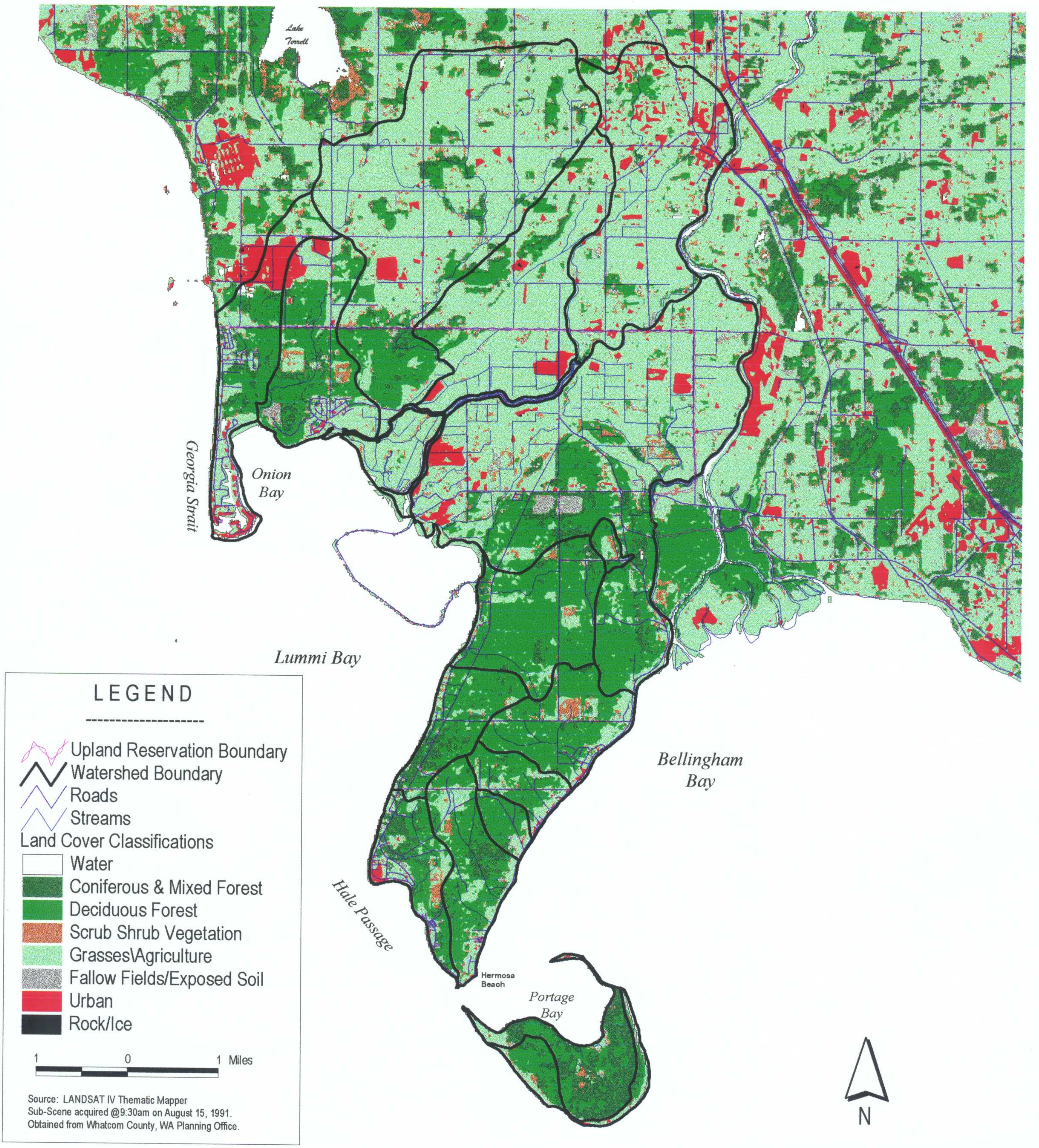

Figure 2.4 Land Cover Type of the Lummi Reservation and Environs

2.7 SURFACE WATER RESOURCES

Surface waters in the study area include the Nooksack River, the Lummi River, sloughs, small streams, roadside and agricultural ditches, springs, wetlands, estuaries, and marine waters. The locations of some of these features are shown in Figure 2.5.

2.7.1 Rivers, Sloughs, Streams, and Ditches

The Nooksack River drains most of western Whatcom County and currently discharges to the marine water of Bellingham Bay near the eastern extent of the Reservation. Prior to 1860, the Nooksack River discharged primarily into Lummi Bay by way of the channel presently used by the Lummi River (WSDC 1960, Deardorff 1992). In 1860 a log jam blocked the Nooksack River and diverted it to a small stream that flowed into Bellingham Bay (WSDC 1960). Since that year, due to the increased commercial value of the river that resulted from its proximity to sawmills along Bellingham Bay, considerable effort has been expended to keep the Nooksack River discharging into Bellingham Bay (Deardorff 1992). The stream remaining in the Nooksack River's old channel has been called the Lummi or Red River (WSDC 1960).

In the 1920s, a reclamation project was initiated to both construct a dike to keep back the sea along the shore of Lummi Bay, and to construct a levee along the west side of the Nooksack River (Deardorff 1992). This project, which was started in 1926 and completed in 1934, initially resulted in the near complete separation of the Lummi River from the Nooksack River. However, when salt water intrusion onto the newly reclaimed farm lands and damage to the dam at the head of the Lummi River occurred during flooding, the dam was replaced with a dam and spillway structure (Deardorff 1992). This spillway structure was also damaged over the years during high flow conditions and was most recently replaced by a culvert structure that allows flow into the Lummi River only during high flow conditions. Levees were also constructed along the Lummi River to prevent salt water intrusion onto adjacent farmlands.

The dike and levee construction activity was accompanied by agricultural ditching to drain fields and wetland areas. Based on 1887-88 topographic surveys, Bortleson et al. (1980) estimated that wetlands located landward of the general saltwater shoreline (subaerial wetlands) in the lower Lummi River watershed have decreased from approximately 2.0 square miles (mi^2) to 0.1 mi^2.

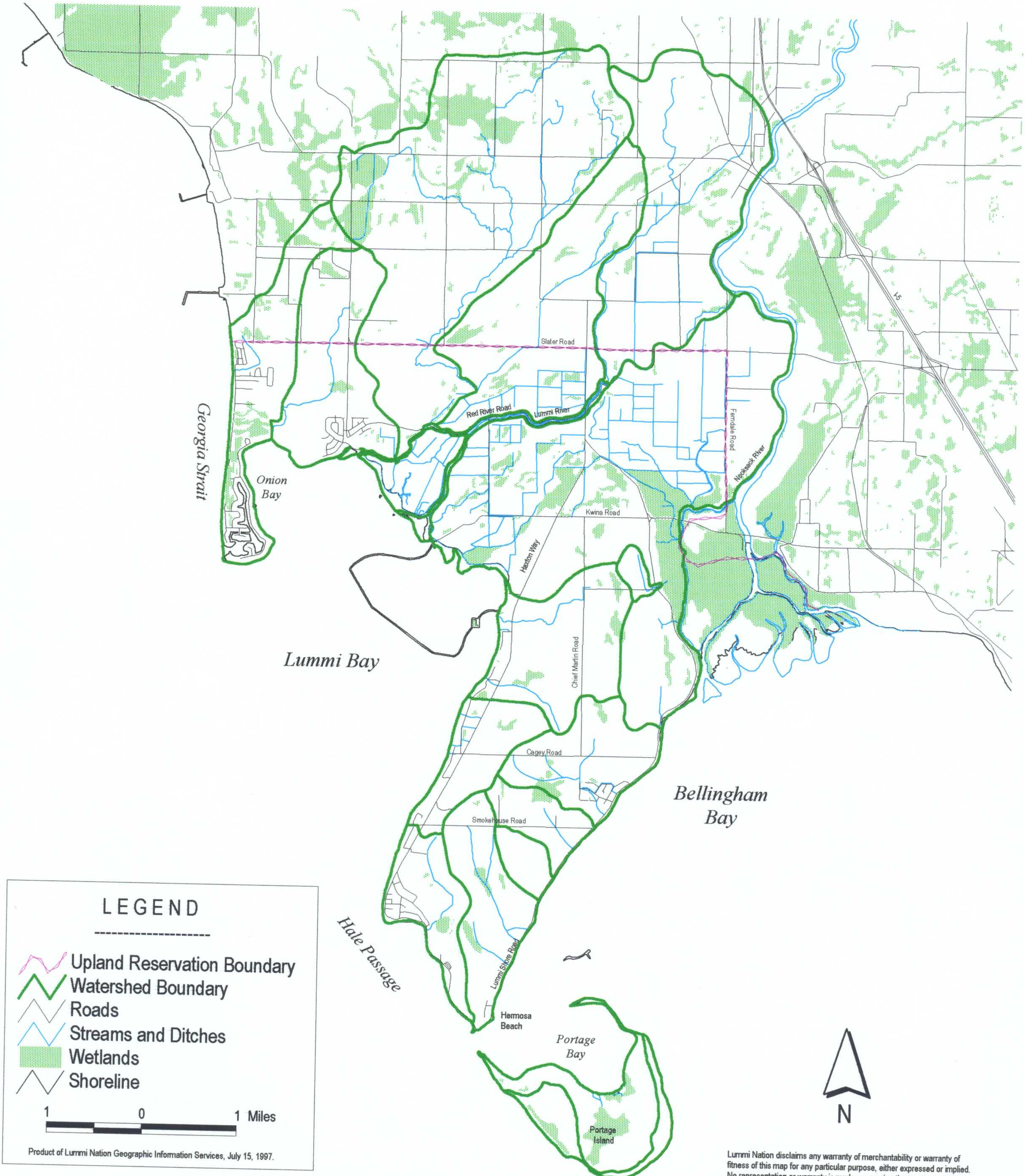

Figure 2.5 Surface Waters of the Lummi Reservation

In general, the Lummi River currently carries storm water runoff from the Ferndale upland as well as the drainage from a complex network of agricultural ditches in the floodplain. Tidal waters enter the Lummi River from Lummi Bay twice daily, reaching as far upstream as Slater Road at extreme tides. Although currently there is rarely Nooksack River water flowing in the Lummi River channel, available data indicate that the flow in the Lummi River was around 200 cfs as recently as 1955 (WSDC 1964).

The Nooksack River reach located on the Lummi Reservation is tidally influenced. Streamside levees are in place to protect agricultural lands from floods and saline water in the channel. Several named sloughs, which are the remains of former river channels, have been incorporated into the agricultural drainage network built on the floodplain of the Lummi and Nooksack rivers. Kwina Slough, a distributary channel of the lower Nooksack River, is the water source for the Sea Ponds salmon hatchery and the Mamoya salmon rearing ponds.

There are several mapped and previously unmapped streams on the Reservation. Most of the unmapped streams have poorly defined channels and contain surface flow only during the October through May period. The approximate locations of these streams were identified as part of the storm water facilities inventory. No flow was observed during a field survey of all Reservation streams in late August 1996.

2.7.2 Springs and Wetlands

Upland springs, which are commonly ground water discharge zones for shallow perched aquifers, are found throughout the Reservation. When water moves downward in permeable sand or sand and gravel lenses and encounters relatively impermeable clay, it moves laterally along the top of the clay layer until the layer either intercepts the land surface or a more permeable layer. A seep or spring occurs if the interception point is the land surface and wetlands may occur if the interception point is a topographic depression in the land surface. In addition to upland springs, springs occur along the shoreline below the ordinary high water line at numerous locations throughout the Reservation.

Historically, springs emerging along the slopes of the uplands served as a water supply for the Lummi people. In many cases they are part of a wetland system where the water infiltrates along the lower terraces to return to ground water. The springs are important for wildlife habitat and for aquifer recharge and protection. Upland aquifers, which provide the primary Reservation drinking water supply as well as salmon egg incubation and rearing water for the hatchery program, have experienced depletion and salt water intrusion. Where it occurs, the infiltration of fresh water along shorelines provides a buffer against salt water intrusion.

The wetlands in the upland areas are palustrine (i.e., marshes, wet meadows, swamps, small shallow ponds), generally forested wetlands that are often seasonally rather than permanently wet. Many of these wetlands were created by drainage disruption during historical logging and road construction. Some of the wetlands created by the drainage disruptions perform significant functions including: storm water peak flow attenuation, storm water quality enhancement, aquifer recharge, and aquifer protection from sea water intrusion. They are also valuable for wildlife habitat and the presence of plants with traditional cultural significance.

Protection of wetland functions is critical to protecting the Reservation water supply and tideland resources. The U.S. Environmental Protection Agency has funded a comprehensive wetland inventory on the Reservation (to be completed by December 1999) and the development of a wetland conservation plan for the Reservation. The inventory and the wetland conservation plan will be the basis of the wetland management program for the Reservation.

Most of the formerly extensive wetlands of the Lummi River floodplain have been diked, drained, filled, and cultivated since the late 1800s. Low areas near some of the sloughs still reflect the rich and complex wetland habitat that covered most of the lower floodplain before human alteration. Small estuarine wetlands lie in sheltered, low energy areas at Onion Bay, Neptune Beach, Portage Island, and adjacent to the Aquaculture dike.

Road construction and agricultural activity have altered the wetlands north of Marine Drive adjacent to the Nooksack River. South of Marine Drive, many of the Nooksack River delta wetlands have been physically altered by the accumulation of sediment at a high rate. The Nooksack River delta was identified as the fastest growing delta in Puget Sound, with a progradation of approximately 1 mile over the 1888 - 1973 period (Bortleson et al. 1980). In addition to the delta progradation, the wetlands of the Nooksack River delta are likely affected by the low instream flows and poor water quality that characterizes the river during some summer months.

On the west bank of Kwina Slough, areas that were marine beaches in 1900 have developed into wetland areas as the Nooksack River has prograded off shore. Former beach sands and gravels have been mined in a few locations. Beaver activity is common in this area of the Reservation.

These palustrine/estuarine emergent wetlands of the lowlands/floodplains are significant for water quality enhancement, flood reduction, storm water attenuation, fish habitat, wildlife habitat, and for plants with traditional cultural importance. The estuarine wetlands provide critical juvenile rearing habitat for migrating salmon, herring, smelt, and other finfish and shellfish.

The significance of these wetlands is increasing as wetlands are altered and destroyed off-Reservation in the upper Nooksack River watershed. These lowland wetlands reduce the water quality impacts of off-Reservation urban development and agricultural land uses on Lummi commercial and subsistence shellfish beds in Portage and Lummi bays. Protecting and enhancing floodplain and estuarine wetlands is essential to preserving and/or restoring the interdependent fish, shellfish, and wildlife habitat.

Remnants of what were once extensive high value wetlands are located on Sandy Point between Sucia Drive and the Sandy Point marina. Road construction and drainage facilities now limit tidal inundation, but wildlife and wetland vegetation is abundant. Plants of traditional cultural significance have been identified in this area. Farther north on Sucia Drive, formerly dry and seasonally wet areas are now permanently flooded as a result of road construction that blocked natural drainage.

A comprehensive inventory of Reservation wetlands is being conducted as funding allows. Sources of information for areas not inventoried in field studies include the *Whatcom County Soil Survey* (USDA 1992) and the 1987 U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory Maps. Because the upland areas of the Reservation are largely covered by forest, field inventories have identified numerous wetland areas not identified in the National Wetland Inventory Maps. The USFWS wetlands location data for the floodplains and Sandy Point are more reliable than for the forested areas.

2.7.3 Estuarine and Marine Waters

Estuarine waters grade to marine waters of the Reservation in Lummi Bay, Portage Bay, portions of Bellingham Bay and Hale Passage, and the shoreline along Georgia Strait. Saline water moves across tideflats and into the Lummi and Nooksack river channels twice daily with the tidal cycle. The salt water underlies the less dense fresh water and moves as a wedge upstream. Tidal effects in the Nooksack and Lummi rivers have been observed as far upstream as Slater Road.

Estuarine waters of the Nooksack and Lummi River deltas form the interface between marine and fresh water. Estuarine waters are important habitat for juvenile and adult salmon as they acclimate to either saline or fresh waters during their seaward and landward migrations respectively.

Estuarine wetland ecosystems in general are considered to produce more biomass for their area than any other natural ecosystem on earth. The complex and rich aquatic resources that provide feeding grounds for fish also attract a large variety of wildlife. The estuaries of the Lummi and Nooksack rivers are a part of a major Pacific coast flyway for ducks, geese, swans, and shorebirds. These estuaries are also habitat for the threatened and endangered bald eagle and peregrine falcon.

Small, estuarine marshes in Lummi Bay occur in sheltered fringes of diked areas. Lummi Bay tideflats are extensive and rich in resources for tribal subsistence and as wildlife feeding areas. Less extensive tideflats at Gooseberry Point, Stommish, and Portage Bay are also important to the tribal economy and culture.

2.8 STORM WATER RUNOFF

As shown in Figure 2.5, there are numerous intermittent streams, roadside drainage ditches, and agricultural drainage ditches on the Reservation. These channels convey storm water to either the surrounding marine waters or to the flood plains of the Lummi and Nooksack rivers. Although there are no streamflow measurements that allow the amount of monthly and annual surface runoff from the Reservation uplands to be accurately quantified, the soil types located on the Reservation suggest that a large percentage of the winter precipitation becomes storm water runoff. As described previously, 87 percent of the soils on the Reservation are in Hydrologic Soil Groups C or D (soils with moderately high to high runoff potential).

Unit runoff maps developed as part of a study of the Nooksack River Basin by the Washington State Department of Conservation (WSDC 1960) estimated that the mean annual runoff from the Reservation is around 15 inches per year. This estimate represents about 42 percent of the mean annual precipitation and about half of the precipitation that occurs from October through May. The amount of runoff is greater in the northern and western parts of the Reservation than near the Nooksack River delta (WSDC 1960).

3. STORM WATER ON THE LUMMI RESERVATION

Precipitation in the form of rain, sleet, hail, or snow is the source of storm water. Storm water occurs when the infiltration rate of the soil and/or the storage capacity of the soil or land surface is less than the amount of rainfall and/or snowmelt that occurs over a given period of time.

The infiltration rate of porous surfaces (e.g., sand and gravelly soils, vegetated soils) is relatively high. Consequently, there is storm water runoff only during larger precipitation events. In contrast, the infiltration rate of impermeable surfaces (e.g., roads, paved parking lots, roofs, driveways) is essentially zero and there is storm water runoff as soon as the very low storage capacity of the surface is exceeded. As a result, runoff from impermeable surfaces can occur during small storms.

Watersheds that include wetlands, reservoirs, detention basins, rain water harvesting cisterns, and infiltration trenches or chambers have greater storage capacity and consequently less storm water runoff from common precipitation events than paved or built over landscapes.

Storm water moves from areas of high elevation to areas of low elevation in response to gravity. Storm water that occurs on the Reservation discharges directly to the surrounding tribal tidelands and marine waters, discharges to the Lummi/Nooksack River floodplain, or infiltrates into the underlying aquifer system. The rate of storm water movement is affected by the characteristics of the surfaces that the storm water encounters as it flows downhill. Vegetated surfaces offer greater resistance to storm water movement and greater infiltration opportunities than paved or compacted surfaces.

3.1 STORM WATER FACILITIES INVENTORY

An inventory of storm water facilities on the Reservation was conducted during February and March 1997. Storm water facilities are defined as culverts, bridges, tide gates, catch basins, roadside ditches, and agricultural ditches. During the inventory, water was flowing in all or most of the roadside and agricultural ditches. Some of the facilities were completely underwater during initial visits and were revisited later in the year when the water had receded.

The purpose of the inventory was to:

1. Identify and map where culverts and bridges are located on the Reservation;
2. Identify and map the locations of roadside and agricultural ditches on the Reservation;
3. Describe the storm water facilities (i.e., diameter, material, condition); and
4. Identify the flow paths of water as it drains from upland areas and the flood plain to determine how each culvert or bridge is related to other culverts, bridges, roadside ditches, agricultural ditches, streams, sloughs, wetland areas, and marine waters.

Whatcom County is responsible for the maintenance of most of the roads and associated storm water drainage systems on the Reservation. Consequently, prior to starting the storm water facilities inventory, the field inventory data sheets and aerial photographs from the culvert inventory conducted by Whatcom County in 1984 were reviewed. Although this information was useful, because it was over 10 years old and a limited field verification effort suggested that some culverts were not accounted for, a new inventory was conducted. The new inventory also allowed the flow direction(s) in ditches and channels, as well as the interrelations between culverts, to be observed. The field observations were recorded on a storm water drainage facilities inventory form (see Appendix A). Appendix A also contains a sample completed field inventory form to illustrate the level of information collected.

Consistent with the approach used in prior inventories of storm water facilities on the Reservation (Whatcom County 1984), facilities were initially located and mapped based on the vehicle odometer. Although the accuracy of this method is only approximately ± 0.05 miles (± 264 feet), it is a practical way to field locate a storm water facility without specialized equipment. The location of a culvert or bridge was further defined in the field by drawing a sketch of the culvert or bridge and identifying nearby landmarks (e.g., driveways, signs, other culverts, other intersections). The information collected on the field inventory forms was entered into a computerized database (ACCESS) and the software program AUTOCAD used initially to map the culvert and bridge locations. The mapped culvert locations were edited as necessary so that they were consistent with field observations.

For greater mapping accuracy, the storm water facilities were located using a global positioning system (GPS) receiver to a horizontal accuracy of ± 5 meters (± 16 feet) during February and March 1998. Incorporation of these location data into the existing database, as well as the addition of facilities identified since the 1997 inventory, will occur in the coming months.

The approximate locations of roadside ditches, agricultural ditches, and unmapped intermittent streams were also identified and mapped as part of the storm water facilities inventory. The approximate locations where roadside ditches are present or absent were identified on 1:24,000 scale USGS topographic maps as staff members drove between storm water facilities. The approximate roadside ditch locations were incorporated into the hydrography GIS data layer. The approximate locations of agricultural ditches were identified from aerial photographs and digitized into the hydrography data layer. The flow directions in many of the agricultural drainage ditches were determined by direct field observations during different tidal conditions. Similarly, the approximate locations of intermittent streams were either determined directly by field observations or surmised based on the topography, observed flow directions, and flow quantity in apparently related culverts.

The 1997 inventory of storm water facilities on the Reservation is presented in Figure 3.1 and in Appendix B. The drainage for the Mackenzie Housing units and the area immediately adjacent to Fisherman's Cove were mistakenly omitted from Figure 3.1.

The locations of these facilities will be incorporated in a revised location map that will be prepared in the coming months to incorporate the location data collected on a GPS unit. The table presented in Appendix B documents the observed relations between storm water facilities on the Reservation. The inventory indicated that at least 48 culverts along the upland parts of the Reservation discharge storm water directly to marine waters or to the flood plain.

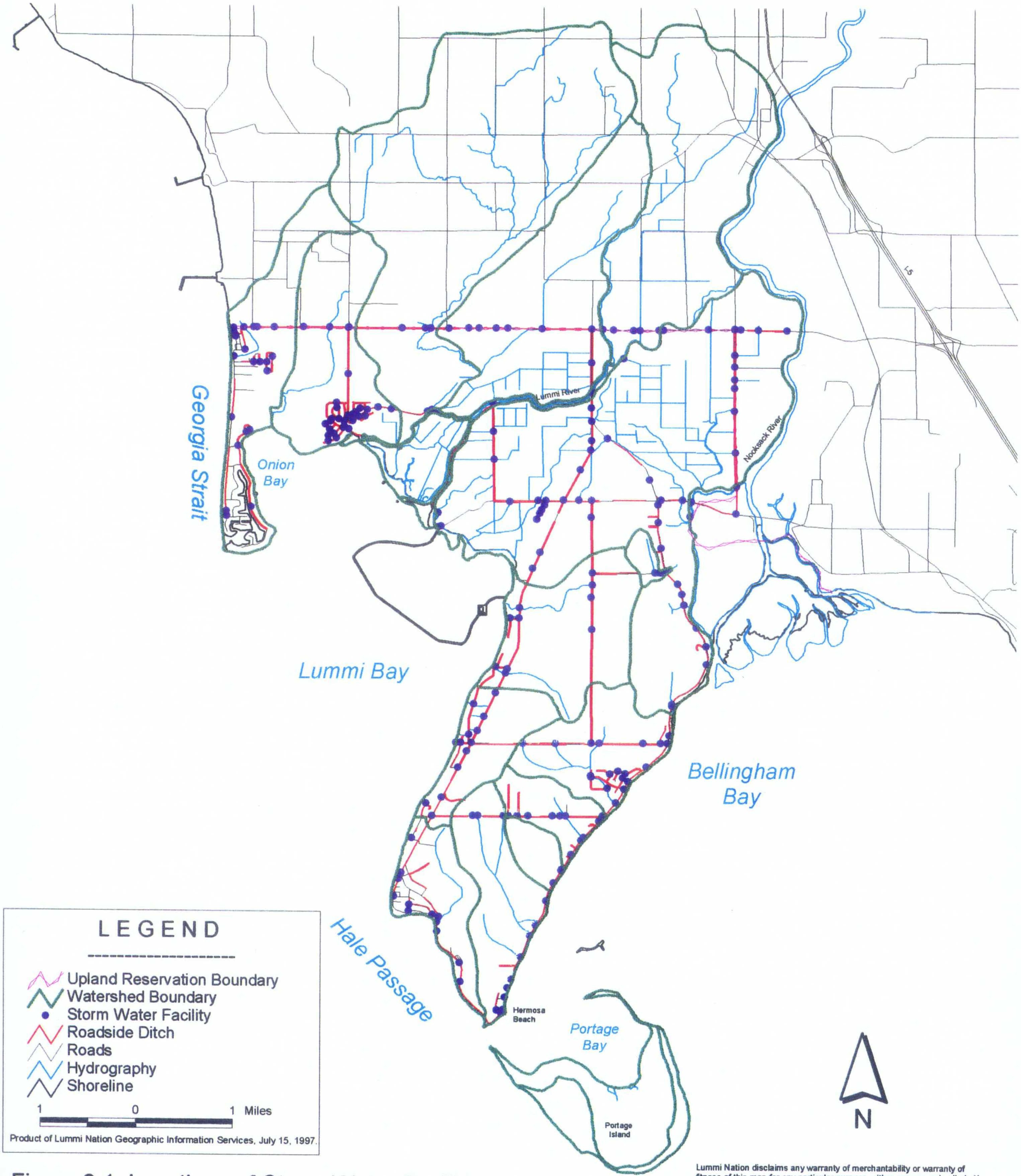

Figure 3.1 Locations of Storm Water Facilities on the Lummi Reservation

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3.2 RESERVATION WATERSHEDS AND STORM WATER

The characteristics of the 19 watersheds on the Lummi Reservations (Figure 2.2 and 3.2) are summarized in Table 3.1. In this section, the dominant land use, the occurrence of storm water and public water supply wells, and other characteristics of the 19 watersheds are summarized. In describing the dominant land use, the coniferous and mixed forest land cover class and the deciduous forest cover class were combined into a single forested land cover/land use category.

Watershed A: Watershed A is crescent shaped and located along the southern and eastern side of Portage Island. The watershed drains into either Hale Passage or Bellingham Bay. About 59 percent of the watershed is forested. The eastern part of the watershed is characterized by forested uplands and steep bluffs. The southern side is comprised of forested uplands and a mix of grasslands, wetlands, and ponded water located in a low-lying area. Beef cattle were grazed on Portage Island in the past and several were observed in dry grassy areas between the ponded water in the southwestern portion of the watershed. There are currently no people living on Portage Island and there are no active ground water wells in this watershed.

Watershed B: Watershed B is dominated by forested land (about 71 percent) and drains the northern and western sides of Portage Island. Storm water from Watershed B discharges primarily into Portage Bay, although a small amount of storm water from along the western extent of the watershed also drains to Hale Passage. Portage Bay is an important shellfish growing area for the Lummi Nation. Relatively large wetland areas in the central part of Watershed B comprise approximately 19 percent of the total drainage area. These wetlands support one intermittent stream that discharge into Portage Bay. There are no active ground water wells in this watershed.

Watershed C: Watershed C is dominated by forested lands (55 percent) and drains the Gooseberry Point area. Water from this watershed is discharged into Hale Passage and to Lummi Bay. Gooseberry Point is one of the more densely populated and heavily used watersheds on the Reservation. The former Lummi Casino (now Lummi Indian Business Council [LIBC] administrative offices), Fisherman's Cove (boat storage, launching, and repair), Northwest Indian College Vocational, Fisherman's Cove Marina (retail grocery), a Ferry Terminal (operated by Whatcom County), the Lummi Tribal Enterprises seafood processing plant, part of the Community Center, the Lummi Assisted Living Center (construction started during Fall 1998), Finkbonner Shellfish Incorporated, Stommish Grounds, and the Gooseberry Point Wastewater Treatment Plant are all located in this watershed. Watershed C also contains a relatively dense residential development along the lowlands and the constructed elements of the MacKenzie Housing Project in the upland areas. Salt water intrusion has occurred in the aquifer in the southwestern part of Watershed C. Several public supply wells near Gooseberry Point have been closed due to high chloride levels induced by overpumping in this watershed. The Lummi Nation currently operates a single public supply well in this watershed (West Shore). Two non-tribal water associations (Gooseberry Point and Georgia Manor) also operate water supply wells in the watershed. There are also several community supply and individual domestic supply wells in the watershed.

Watershed D: Watershed D is about 65 percent forested and drains largely to Bellingham Bay. Residential development is concentrated along Lummi Shore Road in the Hermosa Beach area adjacent to the rich Tribal shellfish growing areas of Portage Bay. Hermosa Beach residents rely primarily on shallow, private, domestic ground water supply wells. The upland areas of this watershed are currently largely undeveloped for residential or other uses. Wetlands extend over large areas along Lummi Shore Road north of Hermosa Beach. The Lummi Nation does not operate any public water supply wells in this watershed. Poor storm water management along Lummi Shore Road has contributed to the collapse of the road into Bellingham Bay in places.

Watershed E: Watershed E is about 79 percent forested with residential development clustered along Lummi Shore Road. The upland area of this watershed, which drains to Bellingham Bay, is largely undeveloped. The Lummi Nation does not operate any public water supply wells in this watershed. Poor storm water management along Lummi Shore Road has contributed to the collapse of the road into Bellingham Bay in places.

Watershed F: Watershed F, a largely forested (about 58 percent of the land area) watershed, drains to Bellingham Bay. Residential development is concentrated along Smokehouse and Lummi Shore roads. The Lummi Nation currently operates its most productive public water supply well (Kinley Way) in this watershed. Poor storm water management along Lummi Shore Road has contributed to the collapse of the road into Bellingham Bay in places.

Watershed G: Watershed G is about 63 percent forested and drains to Bellingham Bay. This watershed contains the Kel Bay housing development and Lummi Auto Recyclers. The area north of Cagey Road and East of Chief Martin Road is a large wetland area that discharges to a wetland area south of Cagey Road and then through the drainage network of the largely unbuilt Kel Bay housing development. Residential development is concentrated along Lummi Shore Road, Cagey Road, and Lightening Bird Lane. The Lummi Nation does not operate any public water supply wells in this watershed; one non-tribal water association (Bel Bay) operates a well in the watershed. The shoreline areas north of Smokehouse Road around the Kel Bay development have experienced salt water intrusion. Poor storm water management along Lummi Shore Road has contributed to the collapse of the road into Bellingham Bay in places.

Watershed H: Watershed H is about 80 percent forested and drains to the resource rich tidelands of Lummi Bay. The shoreline areas of this watershed are relatively dense residential areas. The Balch Road housing project and the Eagle Haven recreational vehicle park are located in the southern upland area of this watershed. The Lummi Nation currently operates two public water supply wells (Balch, Horizon) in Watershed H. Two non-tribal water associations also operate water supply wells in the watershed (Sunset, Northgate-Leeward). In addition, there are at least 10 individual private

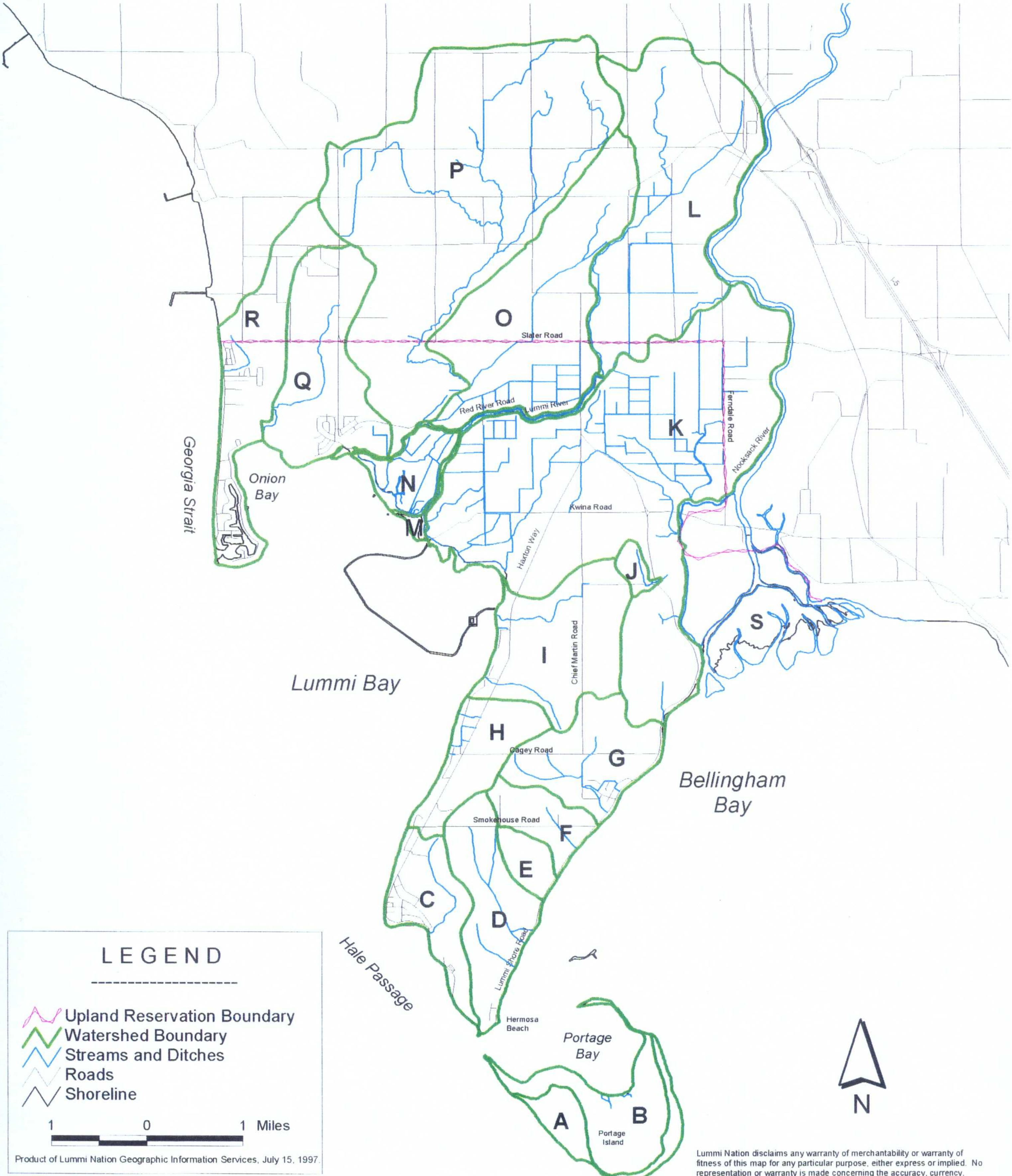

Figure 3.2 Watershed Reference Map

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Table 3.1 Watershed characteristics

Basin ID	Drainage Area (acres)	Receiving Water Bodies	Hydrologic Soil Group[1,2] Group A (%)	Group B (%)	Group C (%)	Group D (%)	Number of Storm Water Facilities[3]	Number of Ground Water Wells	Land Use/Land Cover[4] Water (%)	Coniferous and Mixed Forest (%)	Deciduous Forest (%)	Scrub/ Shrub (%)	Grasses and/or Agricultural (%)	Fallow Fields/ Exposed Soils (%)	Urban, Residential, Industrial (%)	Wetland (%)	Rock (%)
A	307	Bellingham Bay, Hale Passage	5.33	62.09	22.40	10.19	0	0	9.50	20.41	38.29	2.79	18.73	1.68	0.00	7.49	1.12
B	634	Portage Bay, Hale Passage	5.03	70.53	7.45	16.99	0	1	3.28	50.93	19.78	1.91	2.29	1.91	0.00	19.35	0.55
C	583	Hale Passage, Lummi Bay	12.54	51.16	28.35	7.95	12	33	0.00	17.64	37.58	4.46	28.35	3.87	3.87	4.24	0.00
D	791	Portage Channel, Bellingham Bay	0.47	4.90	71.41	23.23	14	28	1.98	10.24	54.30	2.42	25.22	0.88	0.00	4.95	0.00
E	183	Bellingham Bay	0.00	0.00	96.19	3.81	3	2	1.85	8.33	71.30	1.85	15.74	0.00	0.93	0.00	0.00
F	340	Bellingham Bay	0.00	0.00	62.93	37.07	12	11	1.03	1.24	56.91	2.58	30.62	1.03	1.03	5.57	0.00
G	798	Bellingham Bay	0.00	0.77	83.38	15.85	19	14	1.96	2.17	60.99	5.66	21.34	1.96	0.65	5.26	0.00
H	574	Lummi Bay	0.00	13.87	60.23	25.89	16	20	0.30	17.54	62.15	1.80	13.05	2.10	0.00	3.06	0.00
I	1,136	Lummi Bay	0.30	1.82	45.90	51.98	11	16	0.00	6.17	77.25	1.52	9.06	0.61	0.15	5.24	0.00
J	87	Nooksack River Floodplain	0.00	0.00	81.14	18.86	3	0	0.00	13.98	55.98	8.00	21.98	0.00	0.00	0.05	0.00
K	4,696	Bellingham and Lummi Bays	0.59	1.11	27.29	71.01	68	42	0.67	0.57	19.21	3.74	57.70	3.19	0.39	14.53	0.00
L	2,384	Lummi	0.00	0.41	49.45	50.14	5	29	0.29	0.11	4.19	2.62	77.90	1.68	9.18	4.03	0.00

Table 3.1 Watershed characteristics

Basin ID	Drainage Area (acres)	Receiving Water Bodies	Hydrologic Soil Group[1,2] Group A (%)	Group B (%)	Group C (%)	Group D (%)	Number of Storm Water Facilities[3]	Number of Ground Water Wells	Land Use/Land Cover[4] Water (%)	Coniferous and Mixed Forest (%)	Deciduous Forest (%)	Scrub/Shrub (%)	Grasses and/or Agricultural (%)	Fallow Fields/ Exposed Soils (%)	Urban, Residential, Industrial (%)	Wetland (%)	Rock (%)
		River, Lummi Bay															
M	145	Lummi Bay	0.12	1.22	46.51	52.14	6	0	9.76	0.00	2.44	2.44	27.53	3.66	0.00	54.17	0.00
N	333	Lummi Bay	0.00	0.00	0.00	100.00	0	0	4.12	0.00	1.03	4.12	80.21	1.03	0.00	9.48	0.00
O	1,964	Lummi Bay	4.63	2.80	6.32	86.25	10	8	0.09	0.20	8.91	2.31	80.63	1.24	0.46	6.07	0.09
P	4,257	Lummi Bay	8.23	12.38	29.83	49.56	4	63	0.12	0.93	11.15	2.28	69.39	1.67	2.60	11.86	0.00
Q	1,209	Onion and Lummi Bays	1.46	1.14	76.07	21.34	31	21	0.29	9.38	42.14	3.86	32.41	3.72	4.15	4.06	0.00
R	1,078	Lummi Bay and Georgia Strait	17.49	6.26	41.68	34.57	25	37	8.46	1.03	22.49	1.30	32.41	1.95	13.98	18.37	0.00
S	548,800	Bellingham and Lummi Bays	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[1] Hydrologic soils groups for portions of watersheds that extend beyond the Reservation boundary (i.e., Watersheds K, L, O, P, Q, R, and S) generally approximated by distribution of hydrologic soil groups within the Reservation boundary.
[2] ND = Not Determined
[3] Storm water facilities (culverts, catch basins, bridges) inventoried on Reservation only.
[4] Land uses/land cover types largely estimated from LANDSAT image acquired at 9:30 am on August 15, 1991and classified by Whatcom County Planning Department. Estimates from the LANDSAT image were modified to incorporate information on the location and areal extent of wetland locations as identified by the National Wetland Inventory (USFWS 1987) and by a tribal consultant (Arnett 1994).

domestic supply wells clustered along the shoreline of this watershed north of Smokehouse Road. The Lummi Nation operates a biosolids application site along Haxton Way north of Cagey Road in Watershed H.

Watershed I: Watershed I is about 83 percent forested with residential areas concentrated along the shoreline areas and Haxton Way. This watershed drains to Lummi Bay. The Lummi Nation does not currently operate any public water supply wells in this watershed; one non-tribal water association (Harnden Island) operates several water supply wells near the shoreline of this watershed.

Watershed J: Watershed J is a small forested watershed that drains to wetland areas west of Kwina Slough in the Nooksack River flood plain. The Lummi Nation does not currently operate any public water supply wells in this watershed.

Watershed K: Watershed K is about 58 percent covered with grasses and agricultural lands. This watershed contains several dairy operations. Water that enters the Reservation watersheds west of the Nooksack River levee largely drains to the resource rich Tribal tidelands in Lummi Bay. At the time of the 1997 storm water facilities inventory, there were nine culverts that drained to Lummi Bay but only one culvert in the flood plain west of the Nooksack River and Kwina Slough that allows water to drain southward over Marine Drive and into Bellingham Bay. Water in this single culvert, which is commonly dammed along the south side by beavers, has been observed flowing to the north toward Lummi Bay. There is also only a single culvert (with a tide gate) south of Marine Drive near the southern terminus of the Kwina Slough levee. This area south of Marine Drive and west of Kwina Slough is part of the former Nooksack River Delta. It is now a large wetland area with numerous beaver dams and beaver lodges. Ground water in the flood plain is generally saline; the Lummi Nation does not currently operate any public water supply wells in this watershed.

Watershed L: Watershed L, which is about 78 percent grasses and agricultural land, drains to the Lummi River. The Lummi (“Red”) River discharges to the resource rich tidelands of Lummi Bay. This watershed contains several dairy operations, the City of Ferndale, and the City of Ferndale’s wastewater treatment plant. All of these facilities are located north of the Reservation boundary. The Lummi Nation does not currently operate any public water supply wells in this watershed.

Watershed M: Watershed M is comprised of the Lummi River downstream from the Schell Creek/Ditch confluence and waterward of the levee and “Finkbonner Island” in Lummi Bay. Watershed M discharges to Lummi Bay. There are no known ground water wells in this watershed.

Watershed N: Watershed N is dominated by grasses and agricultural lands in the former delta area of the Lummi River. This watershed drains to the resource rich tidelands of Lummi Bay and does not contain any ground water wells.

Watershed O: Watershed O, which is about 81 percent grasses and agricultural land, drains to the resource rich tidelands of Lummi Bay via the remnants of what was shown on some historic maps as McComb Slough. Seeps have been observed along terraces just north of Slater Road. There are also several dairy operations and a gas station north of the Reservation boundary in this watershed. There is also a gas station and fast food restaurant (A&W) within the exterior boundaries of the Reservation in this watershed. Although there are several wells north of the Reservation boundary, there are no active wells within the Reservation Boundaries in Watershed O.

Watershed P: Watershed P is about 70 percent grasses and agricultural lands and drains to Lummi Bay. The portion of the watershed on the Lummi Reservation is largely forested. There are several dairy operations and numerous water supply wells in the watershed north of the Reservation. There is reportedly a productive spring within the Reservation boundary but there are currently no active water supply wells in the portion of the watershed located on the Reservation.

Watershed Q: Watershed Q is about 52 percent forested and drains to Onion Bay. This watershed contains portions of the Tosco petroleum oil refinery and Barlean's Fish packing operation north of the Reservation. The Sandy Point Heights residential development is located in the watershed within the exterior boundaries of the Reservation. The Lummi Nation does not currently operate public water supply wells in this watershed.

Watershed R: Watershed R is not dominated by a single land use but rather contains a mix of forested (23 percent), grasses/agricultural (32 percent), urban/residential/industrial (14 percent), and wetland areas (18 percent). This watershed drains to Georgia Strait and to Onion and Lummi bays. The Sandy Point Wastewater Treatment plant, the Sandy Point Fish hatchery, and a sand and gravel transport company are located within the Reservation boundaries in Watershed R. Portions of the Tosco petroleum oil refinery are located north of the Reservation boundaries in this watershed. The Lummi Nation operates a single ground water well in this watershed to supply the salmon hatchery and some domestic use. Two non-tribal water associations (Sandy Point Improvement Company and Neptune Beach) operate multiple water supply wells on the Reservation in Watershed R.

Watershed S: Watershed S, which is the Nooksack River basin, is largely located upstream from the Reservation boundaries. As noted previously, the Nooksack River drains primarily into Bellingham Bay with flow discharging to Lummi Bay only during high flow conditions and/or when the levee fails. Land use activities upstream from where the Nooksack River enters the Reservation affect both the quality and quantity of water available for tribal uses. For example, the closure of Tribal shellfish beds near Portage Bay in late 1996 has been attributed to the poor quality of the Nooksack River water (DOH 1997). Water quality data collected at the Washington Department of Ecology monitoring station near Brennan (Slater Road) indicates that the Nooksack River water quality does not meet the lowest standard (Class D) for water reclamation and reuse (LIBC 1998b). Use of the Nooksack River water for salmon egg incubation resulted in a mortality rate of about 80 percent at the Seaponds hatchery. The poor water quality led to the development of an egg incubation facility near Sandy Point supplied by well water. The salmon egg mortality decreased to about 10 percent when the egg incubation facility was moved to Sandy Point. The depleted quantity of river water also limits the Lummi Nation's ability to support a salmon rearing pond along Kwina Slough (Parker 1974) and the salmon hatchery along the Seaponds Dike.

4. LAND USE IMPACTS ON STORM WATER QUANTITY AND QUALITY

The quantity and quality of storm water runoff from a geographic area is a function of several interrelated site characteristics including: drainage area, precipitation quantity, rainfall intensity, vegetation, soil properties, land use, and the amount of time between storms. Of these site characteristics, vegetation, soil properties, and land use are often altered during development activities.

In this section, the impacts of land use changes on the quantity and quality of storm water are described based on the scientific literature, the results of a computer model, and an inventory of potential storm water contaminants.

4.1 LAND USE IMPACTS ON STORM WATER QUANTITY

At present, there have been no data collected to quantify how land use changes have affected the amount of storm water on the Reservation. In the absence of site specific data, the available literature was reviewed to determine the expected impacts of land use changes on the amount of storm water on the Reservation. In addition, a computer model was used to illustrate the hydrologic and hydraulic changes that can be expected when forested lands on the Reservation are converted to residential and commercial uses.

4.1.1 Literature Review: Land Use Changes and Storm Water Quantity

The water budget approach, which balances the inflow of water to a system with both the outflow from the system and change in system storage, has been used to model the effects of vegetation change on runoff quantity (Dunne and Leopold 1978). The inflow to a watershed is precipitation, surface water inflow, and/or ground water inflow. The outflow from a watershed is divided among surface runoff, ground water runoff, and evapotranspiration (Lewis and Burgy 1964). If the outflow of water through one route is reduced, either the amount of stored water will increase, the outflow by other routes will increase, or a combination of the two possibilities will occur. In the case where the soil storage capacity is satisfied, or the rainfall intensity (or melt rate) is greater than the infiltration rate, water is lost to the system through surface runoff, return flow, or deep percolation (Dunne and Leopold 1978).

Because vegetation influences a variety of hydrologic processes (e.g., interception, stemflow, infiltration, percolation, surface runoff, evaporation, transpiration, water storage, and erosion), a change in vegetation realigns the water balance and changes the importance of the different outflow routes. For example, the removal of vegetation eliminates interception and transpiration losses and thereby increases the amount of water in the system. The water balance method dictates that the additional water must either infiltrate and increase the soil moisture storage, percolate to the ground water system (to be stored or to runoff as base flow), evaporate, or runoff as surface flow.

Infiltration is the process that indirectly determines the amount of water available for runoff, soil moisture recharge, plant growth, and for deep percolation and ground water recharge (Gifford and Hawkins 1978). If forested lands are converted to residential or commercial uses, the amount of impervious surfaces is increased. Since by definition water cannot infiltrate through impervious surfaces, water cannot increase the soil moisture storage or directly percolate to the ground water system under the covered surface. Infiltration is reduced as forested lands are converted to residential or commercial uses which results in an increase in the amount of runoff water. Because surface runoff is the primary force initiating erosion and transporting sediment and dissolved solids (Branson et al. 1981), an increase in runoff can be expected to result in increased soil loss.

The effects of vegetation change on runoff and erosion have been studied extensively since the early 1900s. Methods used to examine the effects of vegetation change on runoff and erosion include paired watershed experiments, plot studies, and time-trend studies. Paired watershed experiments are probably the most effective method for determining how vegetation change affects hydrological responses. The paired watershed method uses a control basin and one or more treated basins selected for their similarity in size, shape, topography, vegetation cover, past land use, climate, and general location (Ffolliott and Thorud 1975). After a calibration or pre-treatment period and a regression analysis to establish hydrologic relationships between basins, a treatment is applied (e.g., vegetation removal) and data collected for a post-treatment period. Data from the treated watershed is then regressed on the control watershed and differences between the calibration and treatment regressions are interpreted as the effect of treatment (Hibbert 1971).

Numerous studies at forested sites with different climates, soil, and vegetation support the conclusion that increases in water yield following changes to forested lands is related to the amount of precipitation and the amount of vegetation removed (Anderson et al. 1976, Brown et al. 1974, Douglass and Swank 1975, Hibbert 1969, Hornbeck et al. 1970, Hornbeck and Federer 1975, Storey and Reigner 1970, Swank and Miner 1968). The more precipitation and the more vegetation removed, the greater the increase in water yield from a landscape. The increases in water yield will decline if regrowth of vegetation is not controlled.

After reviewing the results of 94 watershed experiments worldwide on both forest and rangeland basins, Bosch and Hewlett (1982) concluded that both evapotranspiration and runoff are affected by the amount, type, and growth form of vegetation cover. Bosch and Hewlett concluded that none of the 94 experiments showed an increase in water yield with an increase in cover (i.e., water yield does not increase with increases in vegetation). Similarly, none of the experiments showed a reduction in water yield with a reduction in cover (i.e., water yield does not decrease with decreases in vegetation).

If forest lands are harvested, and there is less than a 20 percent reduction in watershed forest cover, in general there will not be a detectable increase in annual water yield (Bosch and Hewlett 1982). It has been noted that if watershed forest cover is reduced by more than 20 percent, increases in annual water yield may occur but will generally be too small to detect with currently available streamflow measurement devices (Ziemer 1987).

Most of the increase in annual water yield will occur during the winter high runoff season and during wetter years (Keppeler and Ziemer 1990, Ziemer 1987).

Although increases in water yield may be difficult to detect for harvested forest lands, increases in runoff volume and peak discharge can be readily detected when forest lands are converted to urban land uses (e.g., residential, commercial). Increases in both the impervious surface area and the number of storm water conveyance channels (e.g., curb and gutter systems, roadside ditches) associated with urban land uses results in increased storm water volume, increased peak discharge, shorter amounts of time required to reach the peak discharge, and shorter duration runoff events as the water rapidly drains from the system in the improved conveyance channels.

4.1.2 Computer Model: Land Use Change and Storm Water Quantity

Since there have been no data collected on the Lummi Reservation that allow the effects of land use changes on storm water volume to be quantified, a computer model was used to illustrate the types of hydraulic and hydrologic changes that could occur if forested lands on the Reservation are converted to residential or commercial uses. Hydraulically, largely due to the higher percentage of impervious surfaces, runoff from residential and commercial areas tend to be of greater volume, greater peak discharge, and shorter duration than runoff from forested areas. The hydrologic and hydraulic effects of converting forest lands to agricultural lands are generally less pronounced than converting from forest to residential or commercial land uses.

Increasing the impervious surface area of a watershed increases both runoff volume and peak runoff discharge. The computer model WILDCAT4 and a hypothetical 10-acre forested watershed on the Reservation were used to illustrate the types and magnitude of hydrologic and hydraulic changes that can be expected if forested lands are converted to residential or commercial uses. WILDCAT4 is a public domain computer model based on the SCS curve number method (USDA 1970). The curve number method uses a scale of 0 to 100 to reflect differences in runoff expected for various soils and cover types. The larger the curve number, the greater the runoff volume for a particular storm.

The program uses distributed curve numbers to estimate rainfall excess for a "design rainstorm". A design rainstorm is a timed pattern of rainfall based on the recorded rainfall quantity and distribution over time. The triangular unit hydrograph method is used in the WILDCAT4 computer program to route the rainfall excess and to estimate the storm hydrographs.

As discussed previously, about 87 percent of the Reservation soils are in hydrologic soils groups C or D. The following conditions were used to illustrate how land use changes on the Reservation impact storm water runoff:

- Drainage area: 10 acres
- Design storm hyetograph (i.e., rainfall distribution over time): SCS Type 1A
- Rainfall amount: 2-, 10-, 25-, and 100-year, 24-hour storms

- Land uses and assigned curve numbers (CN): Forest (CN = 78); Residential site with 25 percent impervious surfaces (CN = 98) and 75 percent pervious surfaces (CN=88); Commercial site with 75 percent impervious surfaces (CN = 98) and 25 percent pervious surfaces (CN=88)
- Land slope: 2.5 percent
- Channel length: 1,100 feet

The results of the computer model runs are summarized in Figures 4.1, 4.2, and 4.3. As shown in Figure 4.1, the runoff volume from a storm with a 50 percent chance of occurring during any given year (i.e., 2-year return period) is about 2.7 times greater when the forested area is converted to residential land use and about 3.7 times greater when the forested area is converted to commercial land use. The increased runoff from the converted land suggests that less water is available to infiltrate into the aquifer. For the 100-year event, the runoff volume increased only about 1.7 times when the forested area is converted to residential land use and about 2 times when the forested area is converted to commercial use. This is consistent with the hydrologic maxim that the impact of land use changes on storm water runoff for larger infrequent storms is less than for smaller more common storms.

As shown in Figure 4.2, the peak discharge rate for the storm with a 2-year return period can be expected to increase about 5.2 times when the forested area is converted to residential uses and about 7.4 times when converted to commercial uses. The higher the peak discharge, the greater the erosive power of the water. Similar to runoff volume, the impacts of land use changes on peak runoff discharge decrease with increasing storm size. For the 100-year storm, the peak discharge rate can be expected to increase by about 1.9 times when a forested area is converted to residential and about 2.2 times when a forested area is converted to commercial uses.

As discussed above and as shown in Figure 4.3, the runoff volume (the area under the hydrograph) and peak discharge increases as forested land is converted to residential and/or commercial uses. The surface runoff also begins soon after the start of the storm for commercial and residential land uses. In contrast, the runoff does not begin for the forested land use until over six hours after the start of the storm. For shorter duration storms or smaller sized storm events, runoff from forested land may not occur. Although not represented in Figure 4.3, largely due to the higher percentage of impervious surfaces and the larger number of conveyance facilities (e.g., storm drains, roadside ditches), storm water runoff from residential or commercial areas also tends to be of shorter duration than runoff from forested areas.

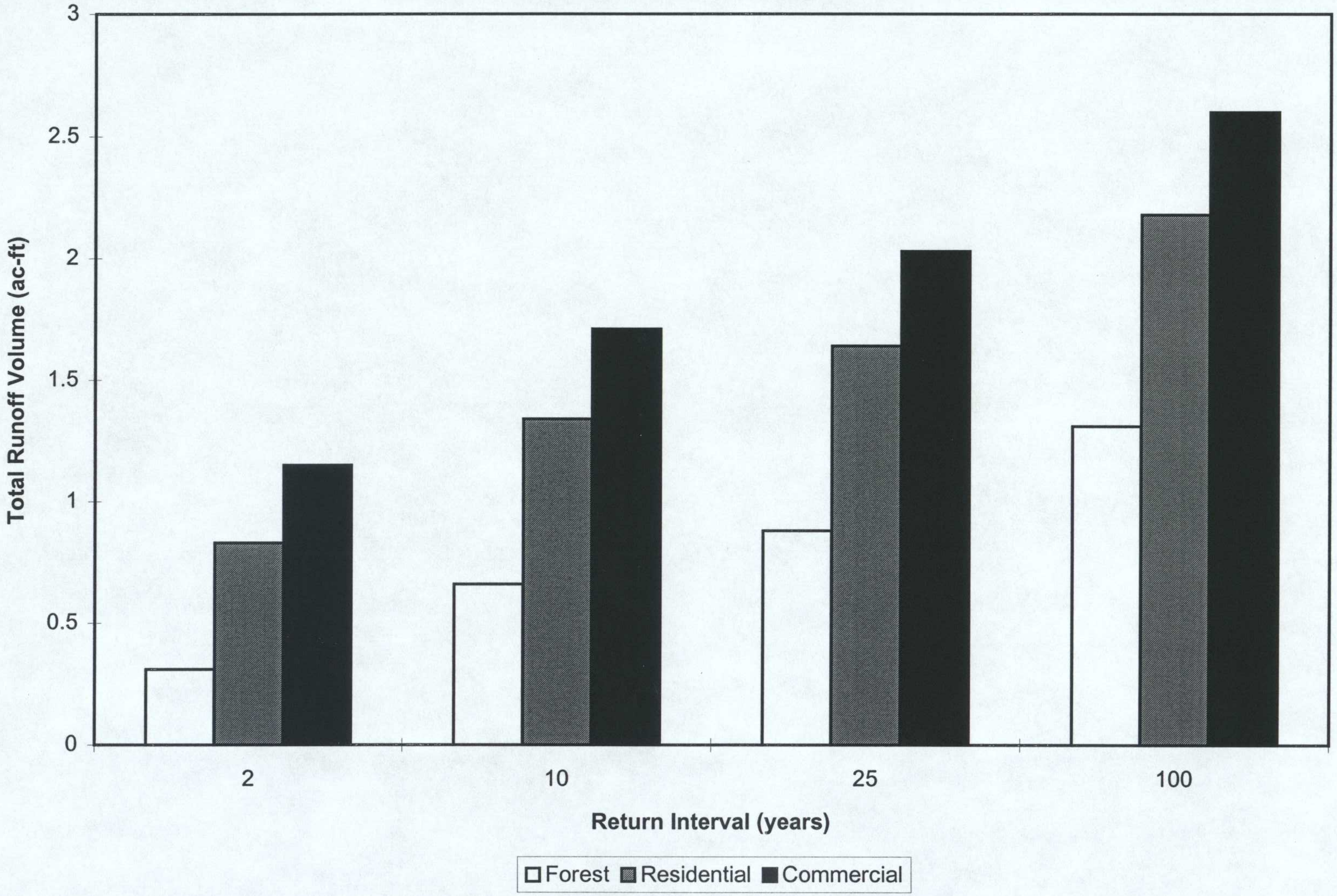

Figure 4.1 Runoff volumes for different land uses for the 2-, 10-, 25-, and 100-year, 24-hour design storm events.

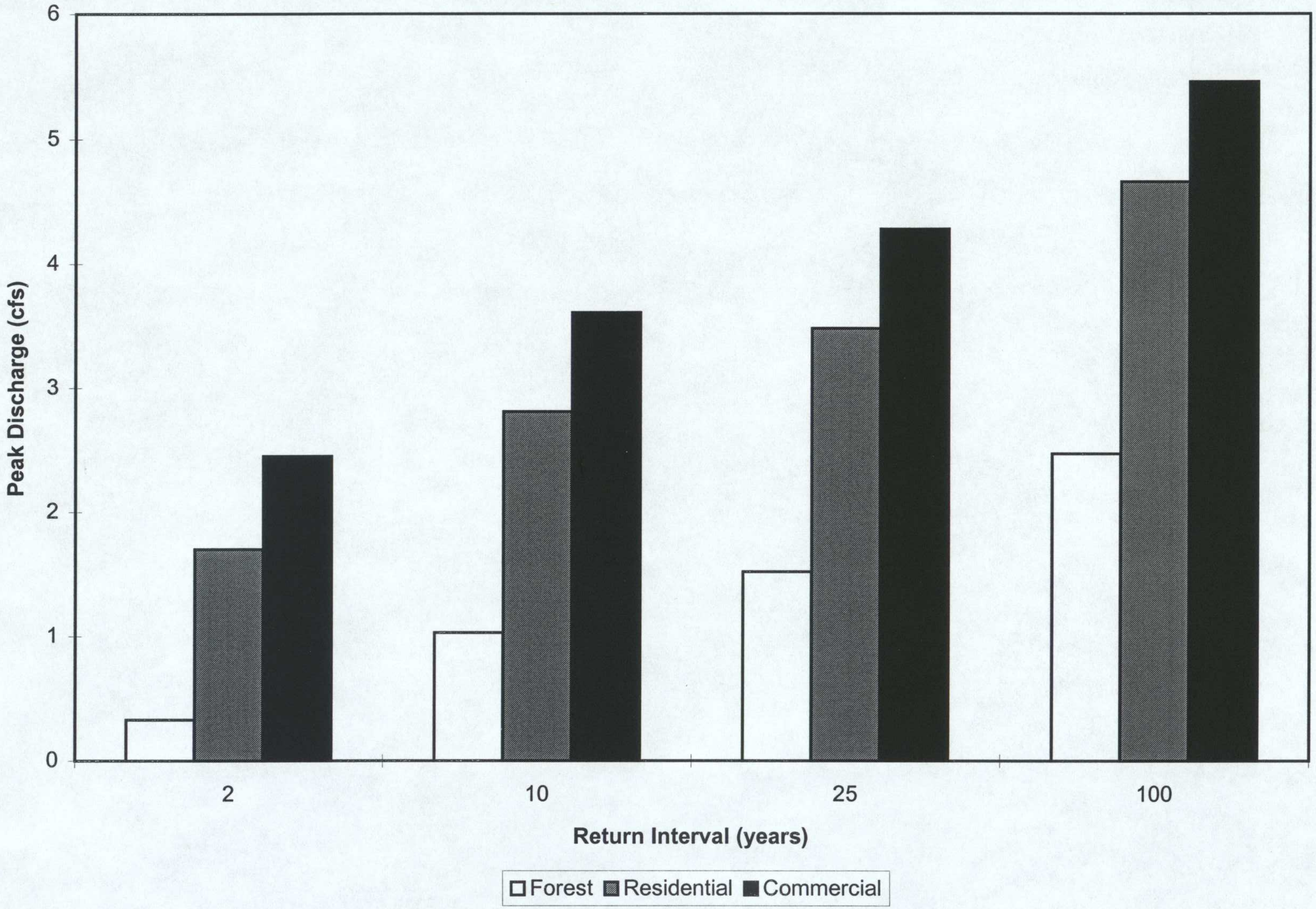

Figure 4.2 Peak runoff flow for different land uses for the 2-, 10-, 25-, and 100-year, 24-hour design storm events.

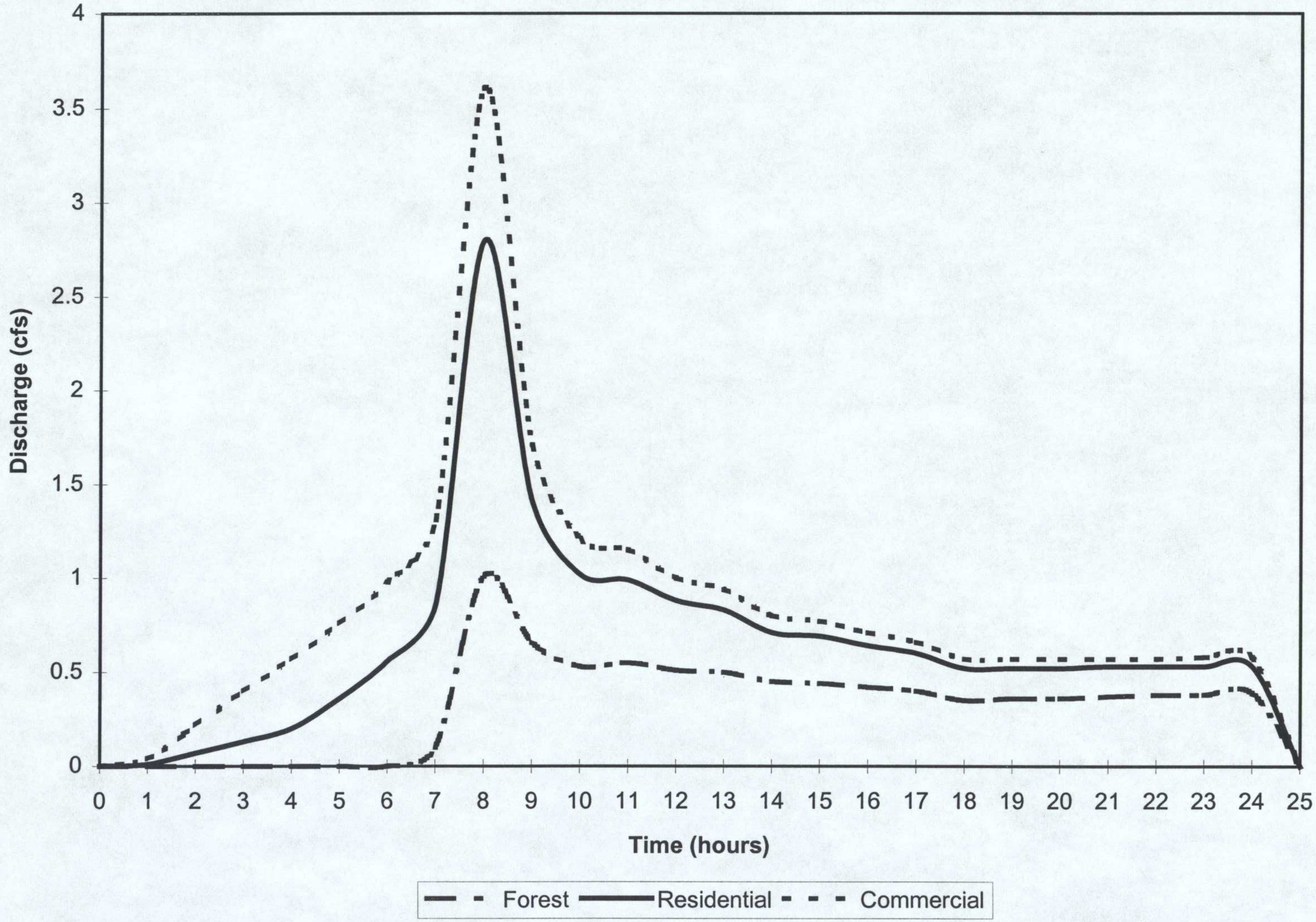

Figure 4.3 Hydrographs for the 10-year, 24-hour storm for different land uses on the Lummi Reservation.

4.2 LAND USE IMPACTS ON STORM WATER QUALITY

Similar to storm water quantity, there have been no water quality data collected that allow the impacts of land use changes on the Reservation and in the watersheds that contribute flow to the Reservation to be quantified. An ambient surface water quality monitoring program was established in 1993 for some of the fresh and marine waters on and adjacent to the Reservation. However, because of the costs associated with testing for metals, pesticides, fertilizers, and hydrocarbons, the water quality samples have only been tested for conductivity, salinity, temperature, fecal coliform, turbidity, pH, and dissolved oxygen.

Without data on the other possible pollutants in the Reservation storm water, the available literature was reviewed to determine the expected impacts of land use changes on storm water quality. In addition, an inventory of potential storm water contaminants sources on the Reservation and in the watersheds that contribute flow to the Reservation was conducted.

4.2.1 Literature Review: Land Use Changes and Storm Water Quality

Urban areas (i.e., residential, commercial, and/or industrial areas) produce pollutants that affect the water quality of streams draining the sites. Not surprisingly, contaminants originating from urban areas differ from other nonpoint sources. The concentration of pollutants in urban storm water runoff is a function of (Whipple et al., 1983):

- the degree of urbanization,
- the type of land use,
- the amount of motorized traffic,
- the density of animal populations,
- the amount of time since the last rainfall event, and
- the amount of air pollution just prior to a precipitation event

In the following paragraphs, a brief history of urban runoff water quality research is presented, the quality of urban storm water runoff is characterized, and the sources of urban pollution as well as the types and quantities of pollutants produced in urban areas are described.

The earliest reported study of urban storm water quality was a 1936 study of runoff from Moscow in the Soviet Union (AWPA 1969). This research was followed by scattered efforts throughout the world and led eventually to the 1978-1983 National Urban Runoff Program (NURP). The NURP was a cooperative U.S. Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), and state and local government effort to conform to section 208 of the 1972 Clean Water Act. Section 208 was contested in court and the case settled in 1977. The 1977 ruling stated that while requiring permits for each pollutant discharge may be cumbersome and complex, the EPA still had to require permits. The court ruled that administrative inconvenience was not an acceptable argument to not regulate nonpoint sources (Athayde et al. 1986). As part of the NURP, the two federal agencies helped twenty-eight cities throughout the country develop urban runoff water quality control plans (Athayde et al. 1986). The overall goal of the NURP was to (Athayde et al. 1986):

> "develop information that would help provide local decision makers, states, USEPA, and other interested parties with a rational basis for determining whether or not urban runoff is causing water quality problems and, in the event that it is, for postulating realistic control options and developing water quality management plans consistent with local needs, that would lead to implementation of least cost solutions."

As of 1986, the USEPA and the USGS had a combined data base collected from 173 urban stations in 31 metropolitan areas. The different city data bases had in common eleven water quality constituents, three storm characteristics, and nine basin characteristics (Drivers and Lystrom 1986).

A nonpoint source is a widespread, non-centralized, randomly occurring source of pollution that varies in location and concentration over time (Jones and Urbonas 1986). As such, urban storm water runoff differs from point sources of pollution (e.g., discharge pipelines from industries, wastewater treatment plants) in four ways (Mancini and Plummer 1986):

- it is a result of a rainfall event,
- it occurs intermittently with short duration pollutant loading and long durations between events,
- there is high variability within and between events, and
- there is a relatively high suspended solid content in the discharge.

Due to the amount of impervious surfaces, urban storm water runoff exhibits an initial flush effect (APWA 1969). The initial flush results from (Whipple et al. 1983):

- a wash off of loosely attached debris due to rain drop impact and surface flow across the impervious surface,
- the re-suspension and/or dissolution of sediment or other pollutants in catchment basins, sewer lagoons, roads, and storm drains that settled out during the last storm event or fell after the last event, and
- the atmospheric particulate matter that is dissolved and brought down by the rain.

The results of studies differ in magnitude but agree that the peak flush effects on receiving waters can exert a biochemical oxygen demand (BOD) which is 40 to 200 times greater than that of normal dry weather effluent from a sewage treatment plant (Vitale and Sprey 1974). The first 3.3 to 9.8 inches of rainfall generally contains over 85% of the BOD (Vitale and Sprey 1974).

The contamination of storm water may occur in the atmosphere, on the ground, on man-made structures, and in the storm drainage system (AWPA 1969). Sources of urban contamination include automobiles, industry, street litter and sediment, lawn and garden chemicals, as well as domestic and feral animals.

Components of automobile exhaust and industrial site emissions that enter the atmosphere, possibly undergo chemical change, and are washed out during the early stages of rainfall events include: lead contaminants, nitrous oxides, hydrocarbons, phosphorus, and sulfides (Whipple et al. 1983). In addition, automobiles pollute the ground surface by depositing oil that contains zinc and phosphorus, worn tire particles containing zinc and oxygen-demanding organic polymers, as well as worn parts containing copper and chromium (Whipple et al. 1983). Storm water runoff from industrial sites can be contaminated with process wastes, raw materials, toxic and hazardous pollutants, oil, and grease (Athayde et al. 1986).

The amount and nature of street litter varies with land use, population, traffic flow, and other indigenous factors (AWPA 1969). The soluble dust and dirt fraction of street litter, containing many of the components previously mentioned, exerts the highest BOD on receiving waters (AWPA 1969). Storm water runoff can contain salt or other ice control chemicals, insecticides, rodenticides, herbicides, and fertilizers. Animal wastes also deteriorate the quality of storm water runoff by contributing organic matter, nitrogen, phosphorus, bacteria, and viruses (Whipple et al. 1983).

The relatively short duration of storm events suggests that the impact on receiving waters may also be for short periods of time and will vary depending on the season and persistence of the pollutant. The NURP found that pollutant concentrations in urban runoff vary considerably during a storm event, from event to event at a given site, and from site to site in a given city and across the country (Tucker 1986). The effects of urban storm water quality on receiving water quality are site specific and depend on (Tucker 1986):

- the type, size, and hydrology of the water body,
- the pollutants that affect the site,
- the site's designated beneficial use,
- the urban runoff quality characteristics, and
- the local rainfall patterns and land use.

4.2.2 Impacts of Construction Activities on Storm Water Quality

As described above, development impacts vegetation and soil properties in a manner that results in higher storm water volumes, higher peak discharges, and lower water quality. Minimizing these impacts from development and maximizing the protection of sensitive and important natural resources is necessary to protect the political integrity, economic security, and the health and welfare of the Lummi Nation, its members, and all persons present on the Reservation.

Development is often associated with some level of earthmoving during construction phases and some level of impact on storm water quantity and quality both during and after the construction phases. Common storm water related impacts of construction include:

- Soil compaction occurs as heavy construction machinery runs over the land surface during clearing and construction related activities. Similar to an impervious surface,

increased soil compaction reduces infiltration and ground water recharge which results in increased surface water runoff.
- Reworking and exposing soil during construction increases opportunities for erosion and sediment transport.

In addition to earthmoving and construction, development is often associated with some level of vegetation removal and replacement with residential, commercial, or community land uses. This change from forested to more urban land uses impacts storm water quantity and quality, particularly during and immediately after the construction phase.

The roots, leaves, and stems of vegetation provides surface roughness. This roughness reduces the speed that water can move overland and acts as a filter to trap sediment. The slower that water flows over a surface, the greater the opportunities for ground water recharge. The more water that infiltrates to the soil, the less water is available to flow overland as storm water runoff. Because less water is available for overland flow, the opportunities for erosion and sediment transport by water are also reduced. Plant roots hold soil particles in place and help to prevent soil loss. In addition, vegetation provides organic matter to the soil and thereby increases its capacity to hold water.

Erosion and sediment control during construction is important because:
- Due to adsorption of pollutants to sediment, transported sediment increases the transport of pollutants.
- Increases in the quantity of surface water can result in downstream erosion and property damage.
- Increased sediment from erosion can obstruct downstream storm water facilities and require increased maintenance.

To reduce the impacts of construction and development activities on storm water and achieve the storm water management goals, appropriate best management practices (BMPs) must be effectively applied. Examples of using BMPs to reduce the impacts of construction/development activities on storm water quantity and quality include:
- Planning development to fit the topography, soils, drainage patterns, and natural vegetation of the site.
- Controlling erosion and sediment from disturbed areas within the project site or area.
- Minimizing the extent of disturbed areas.
- Conducting site disturbance work during the drier parts of the year (i.e., May through September).
- Stabilizing and protecting disturbed areas from runoff as soon as possible.
- Minimizing runoff velocities by minimizing slope length and gradient and protecting natural vegetative cover.
- Implementing a thorough storm water facilities maintenance and follow-up program.
- Constructing properly designed detention ponds, wetlands, infiltration trenches, grass swales, and filter strips.
- Preserving wetland areas.
- Minimizing impervious areas (i.e., paved or compacted areas).

- Conducting pollution prevention activities including public education and household hazardous waste collection and disposal events.
- Anticipating and planning for intense rainfall during construction.

4.2.3 Inventory Of Potential Storm Water Contaminants

The risk that storm water will be exposed to contaminants is determined largely by the current and historic presence/use of contaminants in the area where the storm water occurs. In addition to the sources presented previously, storm water contamination can also result from:

- Misuse and improper disposal of liquid and solid wastes.
- Illegal dumping or abandonment of household, commercial, or industrial chemicals.
- Accidental spilling of chemicals from trucks, railways, aircraft, handling facilities, and storage tanks.
- Improper siting, design, construction, operation, or maintenance of agricultural, residential, community, commercial, and industrial storm water drainage systems and liquid and solid waste disposal facilities.
- Atmospheric pollutants.

An inventory of potential contaminant sources in the Reservation watersheds was conducted to help focus storm water quality management efforts. The contaminants associated with each potential source were identified from the literature as typical for the specified land use (EPA 1993) or from 1995 emissions inventory data provided by the Northwest Air Pollution Authority. The potential storm water contaminants were grouped by the following seven land use categories:

- Construction Sources
- Agricultural Sources
- Residential Sources
- Community Sources
- Commercial Sources
- Industrial Sources
- Industrial Processes

Potential storm water contamination from community sources includes the sewer lines of the Lummi Sewer District. Although the sewer system generally protects storm water quality by replacing septic systems, like all municipal sewer systems, the sewer lines are subject to equipment malfunctions that could result in spills or overflows. In addition, spills or leaks could result from damage during construction activities or from damage caused by natural events (e.g., floods, earthquakes). It is noted that the alarm and emergency response system of the Lummi Sewer District should minimize the impact of any spills

Potential storm water contamination from industrial processes includes direct conveyance onto the Reservation in surface flow and the deposition of atmospheric pollutants originating from the area directly north of the Reservation boundary, the Recomp incinerator just east of the Reservation, or from industries along Bellingham Bay. The Cherry Point Heavy Impact Industrial Zone is located to the north and west of the Reservation watersheds. This heavy impact industrial zone, the largest such zone in Whatcom County, contains two petroleum oil refineries (Tosco and ARCO) and an aluminum plant (Intalco). One of the oil refineries (Tosco) is located adjacent to the north Reservation boundary and is partially in Watersheds Q and R. Previous owners of this facility were Mobil Oil and British Petroleum. In addition to sources within the Cherry Point Heavy Impact Industrial Zone, storm water contamination is possible through the deposition of atmospheric pollutants originating from the Recomp incinerator along Slater Road, the GN Plywood mill, the Encogen NW Cogeneration Plant, and the Georgia-Pacific West Incorporated paper mill in Bellingham.

Table 4.1 summarizes the inventory of potential sources of storm water contamination in the Reservation watersheds, the potential contaminants associated with each source, the watersheds where the potential sources are located, and the receiving water bodies.

Table 4.1. Inventory of Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
1. Potential Construction Sources				
Machinery, earthmoving, soil compaction, vegetation removal	Oils, waste oils, solvents, grease, hydraulic fluids, transmission fluids, antifreeze, acids, paints, miscellaneous cutting oils, miscellaneous wastes, and sediment	All 19 watersheds	Bellingham Bay, Hale Passage, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River	• Temporary sources • Location and size of construction activity varied.
2. Potential Agricultural Sources				
Farm lands used for raspberry, strawberry, silage, forage, grain, and other row crops	Pesticides (e.g., insecticides, herbicides, fungicides), fertilizers, pesticides and fertilizer residue from containers or storage areas; automotive wastes (e.g., gasoline, antifreeze, transmission fluid, battery acid, engine and radiator flushes, engine and metal degreasers, hydraulic fluids, and motor oil)	F, K, L, N, O, P, Q, R, S	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River	• Substantial agricultural lands upstream from the Reservation boundaries and on the Reservation in the flood plain of the Lummi and Nooksack rivers. • Small areas of agricultural land in the upland areas of the Reservation.
Horses, goats, cattle, sheep, and/or llamas	Livestock sewage wastes; nitrates; phosphates; chloride; coliform and noncoliform bacteria; viruses; chemical sprays for controlling insect, bacterial, viral, and fungal pests on livestock	A, B, D, K, L, O, P, Q, R, S	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay	• Substantial dairy operations upstream from the Reservation boundaries and on the Reservation in the flood plain of the Lummi and Nooksack rivers. • Smaller numbers of livestock elsewhere including the Hermosa Beach and Neptune Beach residential areas.
3. Potential Residential Sources				

Table 4.1. Inventory of Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
Single or multi-family homes	Household cleaners, oven cleaners, drain cleaners, toilet cleaners, disinfectants, metal polishes, jewelry cleaners, shoe polishes, synthetic detergents, bleach, laundry soil and stain removers, spot removers and dry cleaning fluid, solvents, lye or caustic soda, pesticides, photochemicals, printing ink, paints, varnishes, stains, dyes, wood preservatives (cresote), paint and lacquer thinners, paint and varnish removers and deglossers, paint brush cleaners, floor and furniture strippers, automotive wastes, waste oils, diesel fuel, kerosene, #2 heating oil, grease, degreasers for driveways and garages, metal degreasers, asphalt and roofing tar, tar removers, lubricants, rustproofers, car and boat wash detergents, car and boat waxes and polishes, rock salt, refrigerants, fertilizers, herbicides, insecticides, fungicides, septage, coliform and noncoliform bacteria, viruses, nitrates, heavy metals, synthetic detergents, cooking and motor oils, bleach, septic tank cleaner chemicals, effluents from barnyards, feedlots,	C, D, E, F, G, H, I, J, K, L, O, P, Q, R, S	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Many residential areas are concentrated along the shorelines of the Reservation. • Residential areas also concentrated along the Nooksack River in towns such as Ferndale, Lynden, and Deming.

Table 4.1. Inventory of Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
	septic tanks, gasoline, water treatment chemicals, and well pumping that induces landward migration of sea water			
4. Potential Municipal Sources				
Roads	Automotive wastes (e.g., gasoline, antifreeze, transmission fluid, battery acid, engine and radiator flushes, engine and metal degreasers, hydraulic fluids, and motor oil), herbicides along road right-of-ways	C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Roads throughout all of the Reservation watersheds except for those on Portage Island. • Similar potential contaminants associated with the Whatcom County Ferry terminal at Gooseberry Point (Watershed C).
Northwest Indian College	Automotive wastes, general building wastes	C, K	Lummi Bay, Bellingham Bay, Hale Passage	• Curriculum is expanding and student housing being added • New campus along Haxton Way expected in the coming years • Off-campus facility at Gooseberry Point
Tribal Schools	Automotive wastes, general building wastes	K	Lummi Bay, Bellingham Bay	• New school expected on the Lummi Peninsula in the coming years
Lummi Tribal Health Center	Automotive wastes, general building wastes	K	Lummi Bay, Bellingham Bay	• Expansion to include a fitness center is underway
Tribal governmental offices	Solvents, pesticides, acids, alkalis, waste oils, machinery/vehicle	C, K	Lummi Bay, Bellingham	• Addition of new archives building and fitness center during 1998

Table 4.1. Inventory of Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
	servicing wastes, gasoline or diesel fuel from storage tanks, general building wastes		Bay, Hale Passage	• Office opened at Gooseberry Point (former casino location)
Biosolids application site	Organic matter, nitrates, inorganic salts, coliform and noncoliform bacteria, parasites, and viruses	H	Lummi Bay	• Complies with 503 Regulations regarding avoiding applications during saturated conditions.
Stommish Grounds	Automotive wastes, general building wastes	C	Hale Passage	• None
Community Center	Automotive wastes, general building wastes	C, D	Hale Passage, Bellingham Bay	• None
Wastewater Treatment Plants	Wastewater, biosolids, treatment chemicals (e.g., chlorine) , automotive wastes, general building wastes	C, L, R, S	Hale Passage, Lummi River, Lummi Bay, Georgia Strait, Nooksack River, Bellingham Bay	• None
Cemeteries	Leachate, lawn and garden maintenance chemicals, automotive wastes	K, O, S	Lummi Bay, Bellingham Bay	• None
Abandoned landfills	Leachate, organic and inorganic chemical contaminants, wastes from households and businesses, nitrates, oils, metals	I, K, S	Lummi Bay, Bellingham Bay	• Types and quantities of contaminants unknown • Hazardous nature of contaminants unknown
Sewer lines (break or malfunction)	Sewage, coliform and noncoliform bacteria, viruses, nitrates, heavy metals, synthetic detergents, cooking and motor oils, bleach, pesticides, paints, paint thinner, photographic	C, D, E, F, G, H, I, J, K, L, O, P, Q, R, S	Lummi Bay, Bellingham Bay, Georgia Strait, Hale Passage	• Potential public health hazard

Table 4.1. Inventory of Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
	chemicals			
5. Potential Commercial Sources				
Ray Beck Construction	Oils, waste oils, solvents, grease, hydraulic fluids, transmission fluids, antifreeze, acids, paints, miscellaneous cutting oils, and miscellaneous wastes	K	Lummi Bay, Bellingham Bay	• None
Lummi Auto Recyclers	Waste oils, solvents, acids, paints, and automobile wastes	G	Bellingham Bay	• Large number of potential contaminants • Storm water management plan underdevelopment
Eagle Haven recreational vehicle (RV) park	Septage, gasoline, diesel fuel pesticides, automotive wastes, and household wastes	H	Lummi Bay	• None
Fisherman's Cove (boat storage, launching, and repair)	Diesel fuel, oil, septage from boat waste disposal areas, wood preservative and treatment chemicals, paints, waxes, varnishes, automotive wastes	C	Hale Passage, Lummi Bay	• None
Fisherman's Cove Marina (retail grocer)	Automotive wastes, general building wastes	C	Hale Passage	• None
The Lummi Tribal Enterprises seafood processing plant	Automotive wastes, general building waste, process wastes s	C	Hale Passage	• None
Finkbonner Shellfish Inc.	Automotive wastes, general building wastes, process wastes	C	Hale Passage	• None
Native American Shellfish Inc.	Automotive wastes, general building wastes, process wastes	K	Bellingham Bay	• None
Warrior Construction	Oils, waste oils, solvents, grease, hydraulic fluids, transmission fluids, antifreeze, acids, paints, miscellaneous cutting oils, and miscellaneous wastes	Q	Onion Bay	• None

Table 4.1. Inventory of Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
Arnold Finkbonner and Sons (sand and gravel hauling company)	Oils, waste oils, solvents, grease, hydraulic fluids, transmission fluids, antifreeze, acids, paints, miscellaneous cutting oils, and miscellaneous wastes	R	Georgia Strait	• None
Barlean's Fish Packing	Automotive wastes, general building wastes, process wastes	Q	Onion Bay	• None
Woodland Nursery	Pesticides (e.g., insecticides, herbicides, fungicides), fertilizers, pesticides and fertilizer residue from containers or storage areas; automotive wastes (e.g., gasoline, antifreeze, transmission fluid, battery acid, engine and radiator flushes, engine and metal degreasers, hydraulic fluids, and motor oil)	P	Onion Bay	• None
Golf Courses	Lawn and garden maintenance chemicals, automotive wastes	Q, S	Lummi Bay, Bellingham Bay	• None
Utilities	PCBs from transformers and capacitors, oils, solvents, sludges, acid solution, metal plating solutions (chromium, nickel, cadmium)	C, D, E, F, G, H, I, J, K, L, O, P, Q, R, S	Lummi Bay, Bellingham Bay, Georgia Strait, Hale Passage	• Potential public health hazard
6. Potential Industrial Sources				
Tosco Refining and Marketing (petroleum oil refinery)	Hydrocarbons, solvents, metals, miscellaneous organics, sludges, oily metal shavings, lubricant and cutting oils, degreasers, metal marking fluids, corrosive fluids, other hazardous and nonhazardous materials and	Q, R	Lummi Bay, Georgia Strait	• Large number of potential contaminants • Potential hazard of contaminants

Table 4.1. Inventory of Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
	wastes, diesel fuel, herbicides for rights-of-way, creosote for preserving railroad ties			
Miscellaneous Industries in the Nooksack River Basin	Hydrocarbons, solvents, metals, miscellaneous organics, sludges, oily metal shavings, lubricant and cutting oils, degreasers, metal marking fluids, corrosive fluids, other hazardous and nonhazardous materials and wastes, diesel fuel, herbicides for rights-of-way, creosote for preserving railroad ties	S	Bellingham Bay	• Large number of potential contaminants • Potential hazard of contaminants
7. Potential Sources of Industrial Processes (atmospheric deposition)				
Tosco Refining and Marketing (petroleum oil refinery)	Criteria Pollutants: Volatile Organic Compounds (VOCs), fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: benzene, butanes, cyclohexane, ethylbenzene, pentanes, toluene, trimethylbenzene, xylene, and other toxins in quantities less than 5,000 lbs per year	All 19 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants
Intalco Aluminum Corporation (aluminum plant)	Criteria Pollutants: VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: gaseous flouride	All 19 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage	• Large number of potential contaminants • Potential hazard of contaminants

Table 4.1. Inventory of Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	**Potential Contaminants**[1]	**Watershed(s)**	**Receiving Water Bodies**	**Comments**
			Bay, Hale Passage	
ARCO Product Company (petroleum oil refinery)	Criteria Pollutants: VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: benzene, cyclohexane, ethylbenzene, sulfuric acid, toluene, trimethylbenzene, xylene, and other toxins in quantities less than 5,000 lbs per year	All 19 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants
RECOMP of Washington Inc. (waste disposal, incinerator)	Criteria Pollutants: Fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: aluminum, barium, cadmium, chlorobenzene, cobalt, copper, flourene, hydrogen chloride, lead, manganese, mercury, and silver	All 19 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants
GN Plywood, Inc. (plywood manufacturer)	Criteria Pollutants: VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide Toxic Pollutants: acetaldehyde, acetone, barium, benzene, chlorine, formaldehyde, manganese, naphthalene	All 19 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants

Table 4.1. Inventory of Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
Encogen NW Cogeneration Plant	Criteria Pollutants: VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: ammonia, formaldehyde	All 19 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants
Georgia-Pacific West, Inc (paper pulp mill)	Criteria Pollutants: VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: acetaldehyde, acetone, barium, chlorine, chloroform, dichlorodifluoromethane, ethanol, formaldehyde, hydrochloric acid, methylethyl ketone, methanol, sulfuric acid, and other toxins in quantities less than 5,000 lbs/year	All 19 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants

[1] Potential contaminant listings based on literature (EPA 1993) and 1995 emission inventory information provided by the Northwest Air Pollution Authority. Other than emission inventories, site specific inventories of potential contaminants at each location were not conducted.

5. STORM WATER BMPS

Best management practices (BMPs) related to storm water are generally defined as physical, structural, and/or managerial practices that, when used singly or in combination, prevent or reduce water pollution. Storm water BMPs are intended to minimize the impacts of land use changes on storm water quantity and/or quality. Effective implementation of BMPs should result in the attainment of the Lummi storm water management goals. That is, effective implementation of storm water BMPs should result in:

- maximizing both infiltration and aquifer recharge opportunities,
- minimizing both the amount of storm water and the opportunities for storm water to wash pollutants into aquifer recharge zones, receiving surface waters, and the resource rich tribal tidelands that surround the Reservation uplands, and
- minimizing the downstream impacts of development on storm water quantity and quality.

Three general types of storm water BMPs are source control, runoff treatment, and stream bank erosion control (Ecology 1992).

- **Source Control BMPs:** The goal of source control BMPs is to prevent pollutants from entering storm water. Source control BMPs either eliminate the pollutant source or prevent rainfall or storm water from coming in contact with the pollutant source. Like most pollution prevention activities, source control BMPs are the most cost effective method to eliminate or reduce storm water pollution. Examples of practices intended to control or prevent water quality impacts at the source include: applying mulch or placing covers over disturbed soil at construction sites, building roofs over outside storage areas, identifying and eliminating illegal connections to storm drains, reducing or eliminating the use of a particular pesticide, placing rocks or cobbles at the entry ways to construction sites, and public education initiatives.

- **Runoff Treatment BMPs:** The goal of runoff treatment BMPs is to reduce pollutant loads and concentrations in storm water runoff using physical, biological, and chemical removal mechanisms. Because it is considerably more difficult and expensive to remove sediments and pollutants from runoff than it is to prevent the introduction of these materials into storm water, treatment BMPs should be a second line of defense in storm water management efforts. The purpose of runoff treatment BMPs should be to remove pollutants that could not be controlled by source control BMPs. Examples of practices intended to remove sediment and/or pollutants from storm water runoff include: infiltration and filtration basins, detention basins, biofiltration swales or vegetative filter strips, and oil/water separators.

- **Stream Bank Erosion Control BMPs:** The goal of stream bank erosion control BMPs is to reduce stream bank erosion that results from increased runoff caused by development. The stream bank erosion control BMPs are intended to reduce the frequency and magnitude of bankfull flow conditions. Bankfull conditions are highly erosive and the frequency of such conditions increases substantially as a result of development and the associated increase in impervious surface area. Conventional flood detention methods do not adequately control stream bank erosion since they only decrease the peak discharge rate of the stream but not the frequency and duration of bankfull conditions. Consequently, measures that detain runoff flows and measures that physically stabilize eroding stream banks are identified as stream bank erosion control BMPs. Examples of practices intended to reduce stream bank erosion include: infiltration basins or trenches, detention basins, vegetative stream bank stabilization, bioengineering methods, and structural stream bank stabilization.

Storm water management BMPs can be temporary or permanent. Temporary BMPs are in place for a year or less and are often used during the construction phase of a project. Examples of temporary BMPs include rocked entry ways to construction sites, sediment ponds, and covering exposed soils with mulch. Examples of permanent BMPs include infiltration trenches, detention ponds, and biofiltration swales. Some temporary BMPs can be planned into a development so that they become permanent BMPs as completion of various phases of the development occur. For example, a rocked entry way can later serve as the base for a paved roadway. Similarly, a sediment pond installed for the construction phase of a development could be modified and used as a detention pond for the developed area. Appropriate storm water BMPs should be the first construction phase for projects regardless if the BMPs are temporary or permanent.

In this section, storm water BMPs are separated into two categories: BMPs for construction sites, and BMPs for urban areas. A brief description is provided for each of the identified BMPs. Expanded descriptions of each BMP are available on-file at the Lummi Natural Resources Department (Water Resources Division) and in the literature (MPCA 1989, EPA 1992, Ecology 1992, MWCOG 1992, IDHW 1996, EPA 1996) and have not been reproduced in this technical background document.

5.1 CONSTRUCTION SITE BMPs

Although construction site BMPs are primarily directed toward either minimizing erosion or controlling offsite sedimentation, they are also intended to minimize the impacts of equipment storage and refueling areas on storm water quality. Minimizing construction site erosion by applying source control BMPs is the first and most cost effective method to eliminate or reduce pollution of storm water from construction sites (Ecology 1992). Source control BMPs at construction sites that reduce erosion include actions such as:

- stabilizing slopes,
- creating natural vegetation buffers,
- diverting runoff from exposed areas,
- controlling the volume and velocity of runoff, and
- conveying runoff away from the construction site.

Sedimentation control is achieved using runoff treatment BMPs such as silt fences, sediment traps, and cobble check dams. The runoff treatment BMPs for sedimentation are only intended to control sediment from unavoidable erosion. Most sites require the use of several types of BMPs to adequately control erosion and sedimentation (Ecology 1992).

Most of the storm water quantity and quality problems from construction sites are associated with specific areas on a site. Accordingly, BMPs have been developed to reduce the problems associated with each these areas (Ecology 1992). The major problem areas on a construction site are: slopes; streams and waterways; surface drainage pathways; enclosed drainage inlets and outfalls; large, flat surface areas; borrow and stockpile areas; adjacent properties; and equipment storage and refueling areas. Each of these problem areas are described briefly below and the BMPs developed to minimize the storm water impacts of each area are summarized in Table 5.1. In general, the most effective BMPs for construction sites are associated with site design and construction management (e.g., maximizing the preservation of natural vegetation, buffer zones, gradient terraces), site and drainage way stabilization (e.g., stabilized construction entrance, bioengineering of drainage pathways), and flow diversions (e.g., interceptor dikes and swales). Timely maintenance of BMPs is obviously an important factor in their effectiveness.

5.1.1 Slopes

Hill slopes and slopes in the site topography greatly increase the potential for erosion. Slopes increase the erosion potential because runoff velocity increases as the slope length (i.e., the distance between the top and the bottom of a hill or slope) and steepness of the slope increase; the higher the runoff velocity, the greater the capacity of the water to detach and transport soil particles (i.e., cause erosion). In general, slope lengths should not exceed (Ecology 1992):

- 300 feet on slopes where the steepness is less than 7 percent;
- 150 feet where the slope steepness is between 7 and 15 percent;
- 75 feet when the slope steepness is greater than 15 percent.

As shown in Table 5.1, problems caused by modifying or creating slopes can be reduced by vegetative stabilization, diversion measures, slope drains, and slope stabilization measures.

5.1.2 Streams and Waterways

The three goals for streams and waterways protection on, near, and/or downstream from construction sites are:

- Increased sediment loads carried by surface runoff from construction sites must not be allowed to enter streams or other waterways.
- Streambanks must be protected from erosion caused by increases in runoff volume and velocity.
- The release rates of increased runoff volume into streams and waterways and the flow velocity in stream channels must be controlled.

As shown in Table 5.1, both vegetative and structural measures can be used to protect streambanks from erosion. As feasible, vegetative and structural measures should be used together.

5.1.3 Surface Drainageways

Development should be planned to maintain and use any naturally stabilized drainageways that may exist on a site (Ecology 1992). Where increases in runoff volume and velocity are anticipated both during and after construction as a result of changes in soil and surface conditions, the capacity of the natural drainageway may need to be increased and the channel stabilized using vegetation and/or structural methods.

As shown in Table 5.1, erosion and sedimentation from surface runoff can be minimized through the use of both vegetative and structural methods. Similar to streams and waterways management methods, vegetative and structural measures should be used together as feasible.

5.1.4 Enclosed Drainage Inlets and Outfalls

Vegetated drainage channels may scour and erode if their capacity is exceeded by the increases in runoff volume and velocity associated with construction activities. To safely convey large volumes and high velocities of runoff, an enclosed storm sewer may need to be used. In deciding when to use a storm sewer, the following factors should be considered (Ecology 1992):

- Are existing enclosed storm sewers available within reasonable proximity to the site or is a natural outlet available.
- The actual size of paved areas and the ratio of paved areas to vegetated areas.

Diversion and surface drainageways are necessary to intercept runoff and convey it to the enclosed storm sewers. Steps must also be taken to prevent sediment from entering the storm sewer system and to remove any sediment from the runoff. The best way to prevent sediment from entering the storm sewer system is to stabilize the site as quickly as possible to prevent erosion and stop sediment at its source. As shown in Table 5.1, the BMPs for enclosed storm sewers include protection of the inlets and outfalls.

5.1.5 Large, Flat Surface Areas

Although erosion rates on steep exposed slopes are greater than on flat or gently sloping areas, all areas of exposed soil are vulnerable to erosion. The clearing, grading, and re-establishment of vegetation should be timed to minimize the extent and duration of exposed areas. Temporary seeding or mulching may be required and diversions, sediment barriers, or traps constructed at the downhill side of disturbed areas to intercept and collect sediment.

5.1.6 Borrow and Stockpile Areas

Borrow and stockpile areas present the same erosion and sedimentation control problems as cut and fill slopes. All of the areas are erodible and runoff should be diverted from the slope faces and conveyed in stabilized channels to designated stable control points.

5.1.7 Adjacent Properties

Protecting adjacent properties and waterways from accelerated erosion and sedimentation can be achieved using methods identified for the other problem areas. The BMPs that can be used include: vegetative filter strips, sediment traps, diversions, grass waterways, rock and washed gravel check dams, and filter fences.

5.1.8 Equipment Storage and Refueling Areas

Petroleum products (i.e., oils, gasoline, diesel oil, kerosene, lubricating oils, and grease) are widely used at construction sites. Most of these products easily adhere to soil particles and other surfaces. Consequently, one way to control these products on-site is to control erosion and sediments using the methods previously described. Other potential pollutant sources found on construction sites include: waste oils, solvents, degreasers, antifreeze, and brake fluids.

5.1.9 Maintenance

A program of ongoing maintenance of temporary and permanent BMPs is an important factor in their effectiveness. Construction sites must be routinely inspected for the condition of BMPs, especially during and after storms, and any necessary repairs performed in a timely manner. Routine maintenance of BMPs should be coupled with on-site evaluation of the effectiveness of the BMPs. Additional BMPs should be deployed if the existing BMPs are not effectively managing the storm water conditions.

As stated initially, source control activities are the most effective way to minimize the impacts of construction activities on storm water quality. Appropriate pollution prevention measures are identified in Table 5.1.

Table 5.1 Storm water BMPs for construction sites

Problem Area	BMP Category	BMP	Description of BMP[1]
1. Slopes	Vegetative Stabilization Measures	Vegetative Buffer Strips	Maintaining a natural vegetative buffer or filter strip at the base of a slope retains sediment on site and is the preferred method for controlling erosion.
		Temporary Seeding	Establishing temporary vegetative cover on disturbed areas where permanent cover is not necessary or appropriate by seeding with appropriate, rapidly growing annual plants can prevent erosion from occurring and trap sediment in runoff from other parts of the site.
		Permanent Seeding and Planting	Establishing permanent vegetative cover (e.g., grasses, legumes, trees, shrubs) on disturbed areas prevents erosion from wind or water and improves wildlife habitat and site aesthetics.
		Mulching and Matting	Application of plant residues, other suitable materials, or matting to the soil surface provides immediate protection to exposed soils during the period of short construction delays or over the winter months.
		Sodding	Establishing permanent grass stands with sod provides immediate erosion protection.
	Diversion Measures	Interceptor Dike and Swale	Placing a ridge of compacted soil or a vegetated swale along the top or base of a sloping disturbed area to intercept runoff and direct it to a stabilized outlet.
	Slope Drains	Pipe Slope Drains	Extending a pipe from the top to the bottom of a cut or fill slope and discharging the collected water into a stabilized water course, a sediment trapping device, or onto a stabilization area can carry concentrated runoff down steep slopes without causing gullies, channel erosion, or saturation of unstable soils.
		Outlet Protection	Placing a rock apron or other acceptable energy dissipating devices at the outlets of pipes or paved channel sections to prevent scour and to minimize the potential for downstream

Table 5.1 Storm water BMPs for construction sites

Problem Area	BMP Category	BMP	Description of BMP[1]
			erosion by reducing the velocity of the runoff.
	Slope Stabilization Measures	Surface Roughening	Providing a rough soil surface with depressions perpendicular to the slope to aid in establishing vegetative cover, reducing runoff velocity, increasing infiltration, and providing for sediment trapping.
		Gradient Terraces	Constructing an earth embankment or a ridge-and-channel with suitable spacing and with an acceptable grade to prevent erosion by intercepting surface runoff and conveying it to a stable outlet at a nonerosive velocity.
		Bioengineered Protection of Steep Slopes	Using a combination of vegetative and structural measures to reduce erosion by reducing runoff velocity, increasing infiltration, and providing for sediment trapping.
2. Streams and Waterways	Vegetative Measures	Vegetative Streambank Stabilization	Planting vegetation along the banks of swales, creeks, streams, rivers, man-made ditches, canals, and impoundments can reduce wave action and runoff velocity and lead to the deposition of water-borne soil particles. Certain reeds and bulrushes can improve water quality by absorbing certain pollutants such as heavy metals, detergents, phenols, and indols.
	Combined Measures	Bioengineering Methods of Streambank Stabilization	Using a combination of vegetative and structural measures to reduce erosion by reducing runoff velocity, increasing infiltration, and providing for sediment trapping.
	Structural Measures	Riprap	Using permanent, erosion-resistant ground cover of large, loose, angular stone to slow the velocity of concentrated runoff or to stabilize slopes with seepage problems and/or non-cohesive soils.
		Gabion	Using rectangular, pervious, semi-flexible rock-filled wire baskets to provide armor protection against erosion

Table 5.1 Storm water BMPs for construction sites

Problem Area	BMP Category	BMP	Description of BMP[1]
		Reinforced Concrete	Using reinforced concrete retaining walls or bulkheads to armor eroding sections of streambank
		Log Cribbing	Using logs to build a retaining structure to protect streambanks from erosion.
		Grid Pavers	Using modular concrete units with interspersed void areas which can be used to armor the streambank while maintaining porosity and allowing vegetation establishment.
		Check Dams	Constructing small dams across a swale or drainage ditch to reduce the velocity of concentrated flows, reduce the erosion of the swale or ditch, and to slow the water velocity to retain sediment on-site.
3. Surface Drainageways	Vegetative Measures	Vegetative Streambank Stabilization	Planting vegetation along the banks of swales, creeks, streams, rivers, man-made ditches, canals, and impoundments can reduce wave action and runoff velocity and lead to the deposition of water-borne soil particles.
	Combined Measures	Bioengineering Methods of Streambank Stabilization	Using a combination of vegetative and structural measures to reduce erosion by reducing runoff velocity, increasing infiltration, and providing for sediment trapping.
	Structural Measures	Grade Control Structures	A variety of temporary or permanent structures can be used to reduce the velocity of runoff in a drainageway by reducing slope length and steepness.
		Lined Channels	In areas where water velocities are high and vegetative or combination measures will not work, the channel can be lined. This approach requires that the area downstream be hardened.
4. Enclosed Drainage	Inlet Control	Filter Fabric Fence	Using a filter fabric fence around a storm drain, drop inlet, or curb inlet to prevent sediment from entering the storm drainage system prior to permanent stabilization of the disturbed area.

Table 5.1 Storm water BMPs for construction sites

Problem Area	BMP Category	BMP	Description of BMP[1]
			Using filter fabric is applicable for relatively small areas (less than 1 acre) flat areas (less than 5 percent slope).
		Block and Gravel Filter	Where flows greater than 0.5 cfs are expected, inlets can be protected by placing wire mesh and filter fabric over the drop inlet, placing concrete blocks length-wise around the inlet with the open ends facing outward (not upward), place wire mesh over the open ends of the blocks, and placing gravel (3/4 to 3 inch gravel) against the wire mesh to the top of the blocks.
		Gravel and Wire Mesh Filter	Where flows greater than 0.5 cfs are expected and construction traffic may occur over the inlet, inlets can be protected by placing wire mesh and filter fabric over the drop inlet and placing at least 12-inches of gravel over the mesh and filter.
		Sediment Traps	Using a small temporary ponding area (either excavated and/or by constructing an earthern embankment) with a gravel outlet to collect and store sediments from exposed sites.
	Outlet Control	Temporary Sediment Pond	Using a temporary ponding area (either excavated and/or by constructing an earthern embankment) with a controlled storm water release structure to collect and store sediments from exposed sites. These sediment ponds should be used for drainage areas less than 10 acres.
5. Large, Flat Surface Areas	See Measures for slopes and other problem areas	See BMPs for slopes and other problem areas	See descriptions presented previously
6. Borrow and Stockpile Areas	See Measures for slopes and other problem areas	See BMPs for slopes and other problem areas	See descriptions presented previously
7. Adjacent	See Measures for slopes	See BMPs for	See descriptions presented previously

Table 5.1 Storm water BMPs for construction sites

Problem Area	BMP Category	BMP	Description of BMP[1]
Properties	and other problem areas	slopes and other problem areas	
8. Equipment Storage and Refueling Areas	See Measures for slopes and other problem areas	See BMPs for slopes and other problem areas	See descriptions presented previously
	Source Control Measures	Pollution Prevention Activities	• Store products in weather-resistant sheds where possible. • Line the storage area with double layer of plastic sheeting or similar material. • Create an impervious berm around the perimeter. The bermed area should have the capacity of 110 percent of the largest container. • Clearly label all products. • Keep storage tanks off the ground and securely fastening lids. • Tell contractors what to do in case of spills and post information for procedures in case of spills. Persons trained in handling spills should be on-site or on-call at all times. • Keep materials for cleaning up spills on-site and easily available. Spilled material should be cleaned up immediately and the contaminated material disposed of properly. • Specify a staging area for all vehicle maintenance activities. This area should be located away from all drainage courses. • All storage sheds, dumpsters, or other storage facilities should be regularly monitored for leaks and repaired as necessary. Workers should be reminded during subcontractor or safety meetings about proper storage and handling of materials.

Table 5.1 Storm water BMPs for construction sites

Problem Area	BMP Category	BMP	Description of BMP[1]

[1] Complete descriptions of these and other BMPs are presented in the, *Stormwater Management Manual for the Puget Sound Basin* (Ecology 1992)

5.2 URBAN BMPs

Similar to storm water BMPs for construction sites, urban BMPs included both structural and non-structural BMPs. Structural BMPs include facilities such as: extended detention ponds, storm water wetlands, infiltration trenches and/or basins, porous pavement, grassed swales, and filter strips. Non-structural BMPs include practices such as: fertilizer management, litter control, street sweeping, catch basin cleaning, household hazardous waste management, and other pollution prevention activities.

5.2.1 Structural BMPs

Eleven structural BMPs are described briefly below and a comparative assessment of the effectiveness of these practices presented in Table 5.2 (MWCOG 1992). The structural BMPs considered are: extended detention ponds, wet ponds, storm water wetlands, multiple pond systems, infiltration trenches, infiltration basins, porous pavement, sand filters, grassed swales, filter strips, and water quality inlets.

1. **Extended Detention Ponds:** Extended detention ponds temporarily store a portion of the storm water runoff for up to 24 hours after a storm using a fixed sized outlet. The intent of the ponds is to allow pollutants to settle out. These ponds are normally "dry" between storm events. Enhanced extended detention ponds are designed to prevent clogging and resuspension. These enhanced ponds are equipped with plunge pools near the inlet, a smaller pool at the outlet, and use an adjustable reverse-sloped pipe to control the outlet (MWCOG 1992).
2. **Wet Ponds:** Wet ponds have a permanent pool of water for treating incoming storm water runoff. Pollutant removal is achieved by gravitational settling, algal settling, wetland plant uptake, and bacterial decomposition. Enhanced wet ponds use a forebay to trap incoming sediments (where they can be removed easily) and a fringe wetland is established around the pond perimeter (MWCOG 1992).
3. **Storm Water Wetlands:** Storm water wetlands are shallow pools that create growing conditions suitable for wetland plants. These wetlands are intended to maximize pollutant removal through uptake by wetland plants, retention, and settling. Storm water wetlands are constructed systems, are not typically located within natural wetlands, and do not replicate all of the ecological functions of natural wetlands. Enhanced storm water wetlands include elements such as a forebay, complex microtopography, and pondscaping with multiple species of wetland trees, shrubs, and plants (MWCOG 1992).
4. **Multiple Pond Systems:** Multiple pond systems is a collective term for a cluster of pond designs that incorporate redundant runoff treatment techniques within a single pond or series of ponds. The pond designs incorporate a combination of two or more of the following: extended detention, permanent pool, shallow wetlands, or infiltration (MWCOG 1992).
5. **Infiltration Trenches:** An infiltration trench is a shallow, excavated trench that has been backfilled with stone to create an underground reservoir. Storm water diverted into the trench gradually exfiltrates from the bottom of the trench into the subsoil and eventually into the aquifer. Pollutant removal is achieved by adsorption, straining,

and microbial decomposition in the soil below the trench and trapping particulate matter within pretreatment areas. Enhanced infiltration trenches have extensive pretreatment systems (e.g., grass filter strips, sump pits, plunge pools) to remove sediment and oil (MWCOG 1992).

6. **Infiltration Basins:** Infiltration basins are impoundments where incoming storm water runoff is stored until it gradually exfiltrates through the soil of the basin floor. Similar to infiltration trenches, pollutant removal is achieved by adsorption, straining, and microbial decomposition in the soil below the basin and trapping particulate matter within pretreatment areas.(MWCOG 1992).
7. **Porous Pavement:** Porous pavement is an alternative to conventional pavement. Runoff is diverted through a porous asphalt layer and into an underground stone/aggregate reservoir from which the storm water eventually infiltrates into the subsoil. Pollutant removal is achieved by adsorption, straining, and microbial decomposition in the subsoil below the aggregate chamber and trapping particulate matter within the aggregate chamber (MWCOG 1992).
8. **Sand Filters:** Sand filters are self-contained sand beds that are placed to receive the first flush of storm water runoff. The runoff is strained through the sand, collected in underground pipes, and returned back to the stream or channel. Enhanced sand filters use layers of peat, limestone, and/or topsoil and may have a grass cover crop. Pollutant removal is achieved by straining and by settling on top of the sand bed (MWCOG 1992).
9. **Grassed Swales:** Grassed swales are earthen conveyance systems in which pollutants are removed from storm water by filtration through grass and infiltration through the soil. Enhanced grassed swales or biofilters use check dams and wide depressions to increase runoff storage and promote greater settling of pollutants (MWCOG 1992).
10. **Filter Strips:** Filter strips are vegetated sections of land designed to accept runoff as overland sheet flow from developments located upslope. These filter strips may be nearly any natural vegetation form, from grassy meadow to small forest. Pollutants are removed by the filtering action of vegetation, deposition in low velocity areas, or by infiltration into the subsoil (MWCOG 1992).
11. **Water Quality Inlets/Oil Grit Separators:** A water quality inlet, also known as an oil/grit separator, is a three-stage underground retention system designed to remove heavy particulates and absorbed hydrocarbons from storm water. Gravitational settling within the first two chambers can achieve partial removal of grit and sediments. An inverted pipe elbow can remove oil by keeping the less dense oil near the surface where it can bind with sediments and ultimately settle. Actual pollutant removal is accomplished when trapped residuals are cleaned out of the inlet (MWCOG 1992).

Table 5.2 A comparative assessment of the effectiveness of current urban BMPs (MWCOG 1992)

Urban BMP Options	Reliability for Pollutant Removal	Longevity[1]	Applicable to Most Developments	Regional Concerns	Environmental Concerns	Comparative Costs	Special Considerations
1. Extended Detention Ponds	Moderate, but not always reliable	20+ years, but frequent clogging and short detention common.	Widely applicable	Very few	Possible stream warming and habitat destruction.	Lowest cost alternative in size range.	Recommended with design improvements and with the use of micro pools and wetlands.
2. Wet Pond	Moderate to high	20+ years	Widely applicable	Arid and high ET regions	Possible stream warming, trophic shifts, habitat destruction, safety hazards, sacrifice of upstream channels.	Moderate to high compared to conventional storm water detention.	Recommended, with careful site evaluation.
3. Storm Water Wetland	Moderate to high	20+ years	Space may be limiting	Arid and high ET regions, short growing seasons.	Stream warming, natural wetland alteration.	Marginally higher than wet ponds.	Recommended
4. Multiple	Moderate to	20+ years	Many pond	Arid regions	Selection of	Most	Recommended

Table 5.2 A comparative assessment of the effectiveness of current urban BMPs (MWCOG 1992)

Urban BMP Options	Reliability for Pollutant Removal	Longevity[1]	Applicable to Most Developments	Regional Concerns	Environmental Concerns	Comparative Costs	Special Considerations
Pond Systems	high, redundancy increases reliability.		options		appropriate pond option minimizes overall impact.	expensive pond option	
5. Infiltration Trenches	Presumed moderate	50 % failure rate within five years.	Highly restricted (soils, ground water, slope, area, sediment input).	Arid and cold regions; sole-source aquifers.	Depending on land use and soils/geology, slight risk of ground water contamination.	Cost-effective on smaller scale, rehabilitation costs can be considerable.	Recommended for appropriate land use with pretreat-ment and geotechni-cal evaluation.
6. Infiltration Basins	Presumed moderate, if working	60 to 100 % failure rate within five years.	Highly restricted (see infiltration trench).	Arid and cold regions; sole-source aquifers.	Depending on land use and soils/geology, slight risk of ground water contamination.	Construction costs moderate, but rehabilitation costs high.	Not widely recommended until longevity is improved.
7. Porous Pavement	High (if working)	75 % failure rate within five years	Extremely restricted (traffic, soils, ground water, slope, area, sediment input).	Cold climates; wind erosion, sole-source aquifers.	Possible ground water impacts; uncontrolled runoff.	Cost effective compared to conventional asphalt when working properly.	Recommended in highly restricted applications with careful construction and effective maintenance.
8. Sand Filters	Moderate to high	20+ years	Applicable (for smaller	Few Restrictions	Minor	Comparatively high	Recommended with local

Table 5.2 A comparative assessment of the effectiveness of current urban BMPs (MWCOG 1992)

Urban BMP Options	Reliability for Pollutant Removal	Longevity[1]	Applicable to Most Developments	Regional Concerns	Environmental Concerns	Comparative Costs	Special Considerations
			developments).			construction costs and frequent maintenance.	demonstration.
9. Grassed Swales	Low to moderate, but unreliable	20+ years	Low density development and roads.	Arid and cold regions	Minor	Low compared to curb and gutter.	Recommended with check dams as one element of a BMP system.
10. Filter Strips	Unreliable in urban settings	Unknown, but may be limited	Restricted to low density areas.	Arid and cold regions	Minor	Low	Recommended as one element of a BMP system.
11. Water Quality Inlets/Oil Grit Separators	Presumed low	20+ years	Small, highly impervious catchments (< 2 acres).	Few	Resuspension of hydro-carbon loadings. Disposal of hydrocarbon and toxic residuals.	High, compared to trenches and filters.	Not currently recommended as a primary BMP option.

[1] Based on current designs and prevailing maintenance practices.

5.2.2 Non-Structural BMPs

In contrast to structural BMPs, non-structural BMPs do not involve the construction of storm water control and/or treatment facilities. Non-structural BMPs are practices such as site planning, storm water facilities maintenance programs, public education initiatives, “good house keeping”, and other pollution prevention practices.

1. **Site Planning:** Effective site planning for new developments can greatly improve the chances of achieving the storm water management objectives. Goals for effective site planning include (MPCA 1989):
    - Reproduce pre-development hydrological conditions.
    - Confine development and construction activities to the least critical areas. The following areas should be avoided when siting projects: along the shoreline of marine waters, lakes, streams, and wetlands; natural drainageways; and areas dominated by steep slopes, dense vegetation, porous soils, or erodible soils
    - Fit development to the terrain.
    - Preserve and utilize the natural drainage system.
2. **Storm Water Facilities Maintenance Programs:** Storm water facilities maintenance programs are important for ensuring that the facilities work as intended. A maintenance program is also necessary for removing sediment and other materials from the facilities before they can be resuspended by subsequent storm water events and washed into receiving waters. For example, catch basins installed in a storm sewer system need to be cleaned out periodically to maintain their sediment trapping ability. During regular inspections conducted as part of a maintenance program, the effectiveness of BMPs and storm water facilities can be evaluated and any corrective actions taken in advance of future storm events.
3. **Public Education and Involvement Initiatives:** Public education and involvement initiatives are important because ultimately individuals are responsible for negative storm water quantity and quality problems. Individuals in the community need to be made aware of household hazardous waste management practices; alternative products available to residential, commercial, and community consumers that are less toxic; and other pollution prevention activities. Community awareness of the importance of keeping storm water ditches and systems free of obstructions and debris contributes to improved functioning of the overall system. As will be discussed in the next section, public education and community involvement will be achieved in the Lummi Storm Water Management Program using a variety of methods including: slide presentation, articles in the community newspaper (*Squol Quol*), and the use of educational video-tapes that can be checked out and viewed at home by community members.
4. **“Good House Keeping”:** “Good House Keeping” is an expression for pollution prevention activities like litter control, street sweeping, and household hazardous waste collection and proper disposal. Litter control involves the removal of litter from streets and other surfaces before runoff or wind moves these materials to surface waters or ground water recharge areas (MPCA 1989). In addition to lawn clippings and leaves (which are a major source of phosphorus in urban runoff), litter that

should be controlled includes pet wastes, trash, oil, and chemicals or toxic compounds used around the house, business, or community. Street sweeping involves the removal of grit, debris, and trash from urban impervious areas (e.g., streets, parking lots, and sidewalks). Because five projects in NURP that studied the effectiveness of street sweeping found that it does not significantly benefit water quality (MPCA 1989), street sweeping is only recommended as a BMP for immediately following winter snowmelt (to remove sand and other debris) and in the fall after leaves have dropped to remove debris accumulated over the spring and summer before the winter rainy season. Household hazardous waste collection and disposal programs are a way to make it convenient for individuals to properly dispose of leftover paints, thinner, oils, solvents, fuels, batteries, anti-freeze, oily rags, and other potentially hazardous waste.

5. **Other Pollution Prevention Practices:** Other pollution prevention practices that have not been previously mentioned include fertilizer management, integrated pest management, nutrient management, and total farm management. Fertilizer management involves controlling the rate, timing, and method of fertilizer application so that plant needs are met while the chance of polluting surface or ground water is minimized (MPCA 1989). Integrated pest management involves controlling the rate, timing, and application method of chemical, biological, and/or structural pesticides or pest control methods. Nutrient management involves ensuring that manure is stored safely and land applied in a manner that does not exceed the agronomic rate of the cover crop. Total farm management ensures that nutrients are effectively managed, chemicals properly stored and applied, and livestock prevented from direct access to waterways.

6. COMMUNITY INVOLVEMENT PLAN

Community involvement is a critical element of a storm water management program. As stated previously, the Lummi Natural Resources Department decided that the largely technical elements of the storm water management program would be completed prior to implementing a community involvement plan. The community involvement plan will be implemented as part of the storm water management ordinance development process that will be described in the action plan for the 1998 through 2000 period (Section 7).

Community involvement in a storm water management program is necessary for a number of reasons including:

- Community participation in developing and implementing the management plan is critical to program success.
- Storm water movement does not follow private property or political boundaries.

The two elements of the community involvement plan are 1) public education and, 2) interjurisdictional coordination and cooperation.

1. **Public Education:** The public education element of the Lummi Storm Water Management Program will include articles in the Lummi Nation newspaper *Squol Quol* and a slide presentation about the Lummi Storm Water Management Program. A slide presentation will be provided to interested groups including the following LIBC commissions, boards, and staff: Natural Resources Commission, Planning Commission, Economic Development Commission, Water Board, Housing Board, Lummi Water District staff, and the LIBC. The presentation will also be provided to audiences such as the Lummi Tribal Health Center, Lummi Tribal School, Lummi High School, and the Northwest Indian College. Because the pollution prevention goals of the storm water management program are similar to some of the wellhead protection program goals, some elements of the public education campaign for the two programs will complement each other.

2. **Interjurisdictional Coordination and Cooperation:** The interjurisdictional coordination and cooperation element of the plan will start within the LIBC. The Lummi Natural Resources Department needs to work closely with the Lummi Planning Department and other LIBC agencies to implement the public education element of the plan and develop a storm water management ordinance.

   Externally, the Lummi Natural Resources Department needs to meet with the environmental officers at the Tosco refinery and the other Cherry Point industries that transport hazardous materials along the northern boundary of the Reservation (Slater Road) to describe the Lummi Storm Water Management Program; identify its concerns about having a heavy impact industry adjacent to the Reservation; request to review their pollution prevention plan, spill prevention and control plan, emissions control plan, storm water quality monitoring plan, and other plans developed to reduce environmental impacts of their operations. Any available reports that evaluate the implementation of the plans should also be requested.

It is anticipated that similar meetings will be held with other parties (e.g., Whatcom County, City of Ferndale) whose actions and regulations related to controlling storm water quantity and quality affect storm water quantity and quality on the Lummi Reservation.

7. 1998 THROUGH 2000 ACTION PLAN

Development and implementation of a storm water management ordinance is the focus of the 1998 through 2000 action plan. The storm water ordinance will define criteria and standards for development and storm water management on the Lummi Reservation. The goal of the ordinance is to prevent the contamination of surface waters on the Reservation, tidelands and estuaries, wellhead areas, and ground water resources. Contamination of these resources by storm water has a direct, serious, and substantial effect on the political integrity, economic security, and the health and welfare of the Lummi Nation, its members, and all persons present on the Reservation.

Ordinances for both the storm water management program and the wellhead protection program will form two new chapters of the Lummi Water code (administered by the Lummi Natural Resources Department). Both the storm water management and the wellhead protection ordinances are scheduled to be drafted by March 31, 1999, have public hearings during 1999, and be adopted during early 2000. Funding for the ordinance development phases of the Lummi storm water management and wellhead protection programs has been secured from the U.S. Environmental Protection Agency (EPA) as part of the Indian General Assistance Program (GAP).

The community involvement plan will be implemented in the coming months and will be part of the storm water management ordinance development effort. Because of similarities between the programs, the community involvement effort of the storm water management program will be implemented in conjunction with the community involvement effort of the Lummi Wellhead Protection Program (LIBC 1997, LIBC 1998a).

The first step in the ordinance development effort was to research and write a storm water management ordinance development plan (LIBC 1998c). A literature review of ordinances and storm water management practices of other governments is currently underway and is scheduled to be completed in January 1999. In addition to the ordinance development plan and literature review, the steps necessary to achieve final approval and adoption of the Lummi Reservation Storm Water Management Ordinance, which is anticipated to occur by February 2000, include:

1. Review existing ordinances and codes in the Lummi Tribal Code that may affect or be affected by a storm water management ordinance.
2. Review storm water management ordinances developed by other jurisdictions (tribal and non-tribal).
3. Develop a draft Lummi Storm Water Management Ordinance.
4. Develop a regulations document that the ordinance will reference.
5. Continue and expand the process of obtaining policy approval.
6. Hold public meetings.
7. Finalize and seek adoption by vote of the Lummi General Council (all voting members of the Lummi Nation).
8. Final enactment by the LIBC.

8. CONCLUSION

The goals of the Lummi Reservation Storm Water Management Program are to: 1) minimize the opportunities for storm water to wash pollutants into aquifer recharge zones and resource rich estuaries and tidelands of the Reservation, 2) minimize the downstream impacts of development on storm water quantity and quality, and 3) maximize the opportunities for infiltration and aquifer recharge. These goals are similar to and consistent with the Lummi Nation Wellhead Protection Program goals (LIBC 1997, LIBC 1998a).

This storm water technical background document is based on a field inventory of storm water facilities on the Lummi Reservation, literature reviews on the impacts of land use changes on storm water quantity and quality, and a literature review on storm water best management practices (BMPs). This plan is intended to serve as the technical basis for a community involvement effort and the development of a Lummi Reservation Storm Water Management Ordinance.

This plan includes:
1. a description of storm water occurrence on the Lummi Reservation,
2. a discussion of how land use changes affect storm water quantity and quality
3. an inventory of potential sources of storm water contamination in the watersheds that drain to the adjacent waterways and aquifer recharge zones,
4. a description of the best management practices (BMPs) available to achieve the storm water management goals,
5. a description of the public involvement plan for the Lummi Reservation Storm Water Management Program,
6. a description of the 1998 through 2000 action plan for the program, and
7. a listing of the scientific literature that helps form the technical basis for the program.

The Lummi storm water management goals can be achieved by taking actions such as:
- Planning development to fit the topography, soils, drainage patterns, and natural vegetation of the site.
- Conducting pollution prevention activities including public education.
- Minimizing impervious areas (i.e., paved or compacted areas).
- Preserving wetland areas.
- Controlling erosion and sediment from disturbed areas within the project site or area.
- Minimizing the extent of disturbed areas.
- Conducting site disturbance work during the drier parts of the year (i.e., May through September).
- Stabilizing and protecting disturbed areas from runoff as soon as possible.
- Minimizing runoff velocities by minimizing slope length and gradient and protecting natural vegetative cover.
- Implementing a thorough storm water facilities maintenance and follow-up program.
- Constructing properly designed detention ponds, wetlands, infiltration trenches, grass swales, and filter strips.

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Appendix A: Lummi Storm Water Facilities Inventory Form

LUMMI STORM WATER DRAINAGE FACILITIES INVENTORY FORM

Date: ______________________ Weather Conditions: ______________

Observations By: _______________________ Water Present?: ☐ Yes ☐ No

Road/Street Name: ____

Intersection Used As Station 0.0 (e.g., Smokehouse Rd./Lummi Shore Road):

____

Direction of Travel from Station 0.0 (e.g., Toward Haxton Way): _____________________

Culvert/Structure Identification Number (1 = Culvert Closest to Station 0.0): ____________

Distance from Station 0.0 (from vehicle odometer): ________________ miles.

Culvert Size (diameter or dimensions): _____________ Units: ☐ Feet ☐ Inches

Material:

- ☐ Galvanized, Corrugated (GALV)
- ☐ Corrugated Steel (C/S)
- ☐ Corrugated Plastic (ADS)
- ☐ Smooth Plastic (SCLAIR)
- ☐ Aluminum (ALUM)
- ☐ Bell and Spigot Concrete (B/S)
- ☐ Tongue and Groove Concrete (T/G)
- ☐ Catch Basins (C/B)
- ☐ PVC (PVC)
- ☐ Unknown (0.00)

Condition:

- ☐ Good (1)
- ☐ Percent Blocked U/S End (2U) ________
- ☐ Percent Blocked D/S End (2D) ________
- ☐ U/S End Smashed/Cut (3U)
- ☐ D/S End Smashed/Cut (3D)
- ☐ Needs Replacement (4)
- ☐ Separated (5)
- ☐ U/S End Eroding (6U)
- ☐ D/S End Eroding (6D)
- ☐ U/S End Needs Extension (7U)
- ☐ D/S End Needs Extension (7D)
- ☐ Needs to be Rechecked (8)
- ☐ Other: ____

Inlet:

Defined Stream Channel Flows into Upstream Side of Culvert? ☐ Yes ☐ No

Roadside Ditch Along Upstream Side and Contributing Flow to Culvert? ☐ Yes ☐ No

Condition of Roadside Ditch Along Upstream Side of Culvert:

- ☐ Grass-Lined (1)
- ☐ Dirt-Lined (2)
- ☐ Shrub/Brush (3)
- ☐ Sparse Vegetation (4)
- ☐ Rocked (5)
- ☐ No Defined Ditch (6)
- ☐ Debris Present (7)
- ☐ Oil Present (8)
- ☐ Other (9)_______

(Please Complete Back of Form)

Outlet:

Defined Stream Channel Flows Away From Downstream Side of Culvert? ☐ Yes ☐ No
Roadside Ditch Along Downstream Side and Collecting Flow from Culvert? ☐ Yes ☐ No

Condition of Roadside Ditch Along Downstream Side of Culvert:

☐	Grass-Lined (1)	☐	Sparse Vegetation (4)	☐	Debris Present (7)
☐	Dirt-Lined (2)	☐	Rocked (5)	☐	Oil Present (8)
☐	Shrub/Brush (3)	☐	No Defined Ditch (6)	☐	Other (9)________

Diagram:

Make a sketch of the culvert/structure crossing and indicate at least the following items:

- ☐ Road/street name
- ☐ Travel direction and distance from Station 0.0
- ☐ Culvert identification number
- ☐ Flow direction(s) upstream <u>and</u> downstream side
- ☐ Landmarks (driveways and street address, road crossings, sewer manholes, etc...)
- ☐ Driveway culverts (indicate location, material, and diameter)
- ☐ Nearby culverts crossing road/street (use culvert identification number)
- ☐ Wetlands and/or areas with ponded water
- ☐ Condition of roadside ditches
- ☐ Location of slope breaks (i.e., where flow direction changes) in roadside ditches and approximate distance from slope breaks to culvert.

LUMMI STORM WATER DRAINAGE FACILITIES INVENTORY FORM

Date: 3/10/97 Weather Conditions: Sunny

Observations By: JRF, FEB Water Present?: ☒ Yes ☐ No

Road/Street Name: Lummi Shore Rd

Intersection Used As Station 0.0 (e.g., Smokehouse Rd./Lummi Shore Road):
Haxton Way/LSR

Direction of Travel from Station 0.0 (e.g., Toward Haxton Way): toward Lummi View

Culvert/Structure Identification Number (1 = Culvert Closest to Station 0.0): 28

Distance from Station 0.0 (from vehicle odometer): 6.33 miles.

Culvert Size (diameter or dimensions): 24" Units: ☐ Feet ☒ Inches

Material:

- ☐ Galvanized, Corrugated (GALV)
- ☐ Corrugated Steel (C/S)
- ☐ Corrugated Plastic (ADS)
- ☒ Smooth Plastic (SCLAIR)
- ☐ Aluminum (ALUM)
- ☐ Bell and Spigot Concrete (B/S)
- ☐ Tongue and Groove Concrete (T/G)
- ☐ Catch Basins (C/B)
- ☐ PVC (PVC)
- ☐ Unknown (0.00)

Condition:

- ☐ Good (1)
- ☑ Percent Blocked U/S End (2U) 0%
- ☑ Percent Blocked D/S End (2D) 0%
- ☐ U/S End Smashed/Cut (3U)
- ☐ D/S End Smashed/Cut (3D)
- ☐ Needs Replacement (4)
- ☐ Other:
- ☐ Separated (5)
- ☐ U/S End Eroding (6U)
- ☐ D/S End Eroding (6D)
- ☐ U/S End Needs Extension (7U)
- ☐ D/S End Needs Extension (7D)
- ☐ Needs to be Rechecked (8)

Inlet:

Defined Stream Channel Flows into Upstream Side of Culvert? ☑ Yes ☐ No
Roadside Ditch Along Upstream Side and Contributing Flow to Culvert? ☑ Yes ☐ No

Condition of Roadside Ditch Along Upstream Side of Culvert:

- ☑ Grass-Lined (1)
- ☐ Dirt-Lined (2)
- ☐ Shrub/Brush (3)
- ☑ Sparse Vegetation (4)
- ☐ Rocked (5)
- ☐ No Defined Ditch (6)
- ☐ Debris Present (7)
- ☐ Oil Present (8)
- ☐ Other (9)

(Please Complete Back of Form)

Outlet:

Defined Stream Channel Flows Away From Downstream Side of Culvert? ☑ Yes ☐ No on Beach

Roadside Ditch Along Downstream Side and Collecting Flow from Culvert? ☐ Yes ☒ No

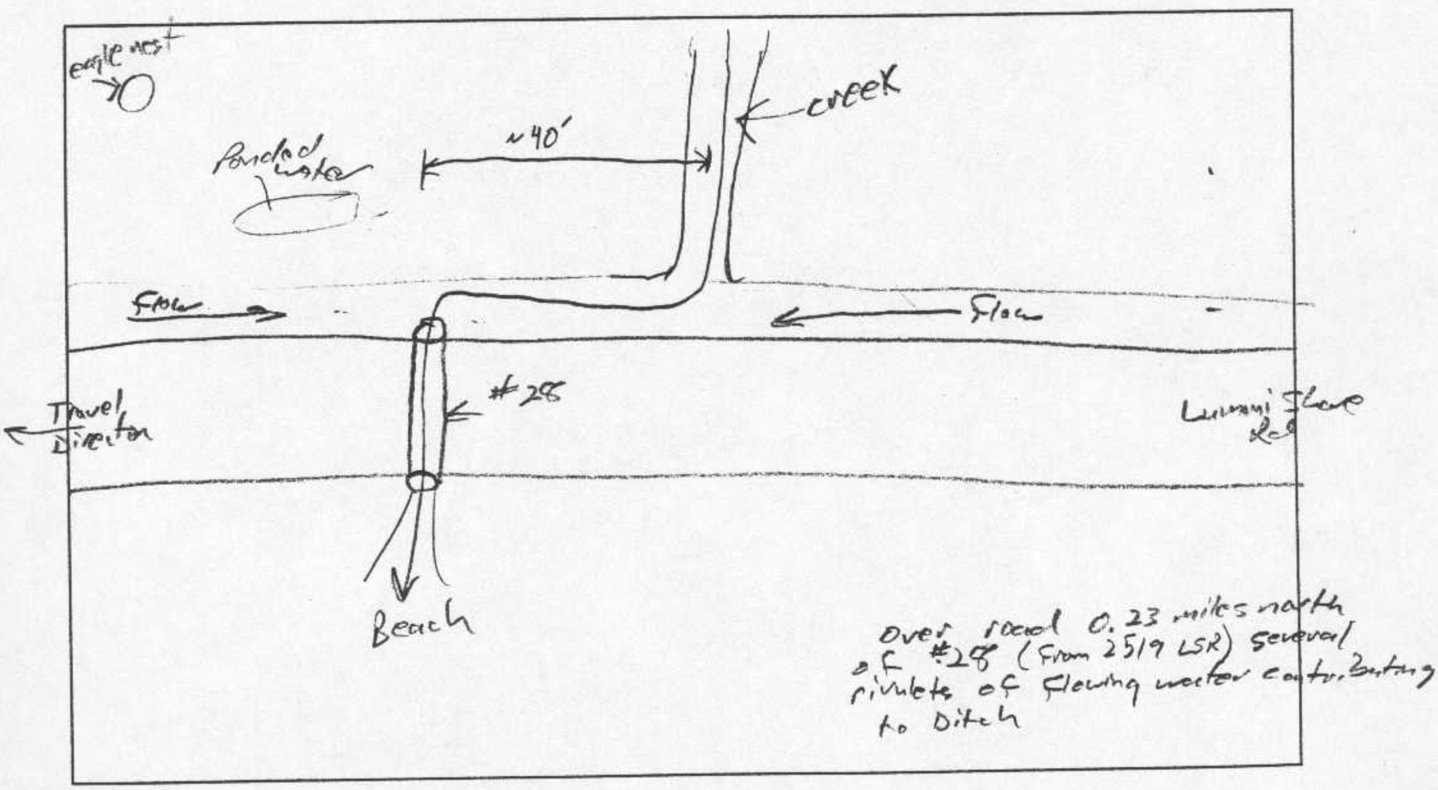
Condition of Roadside Ditch Along Downstream Side of Culvert:

☐	Grass-Lined (1)	☐	Sparse Vegetation (4)	☐	Debris Present (7)
☐	Dirt-Lined (2)	☐	Rocked (5)	☐	Oil Present (8)
☐	Shrub/Brush (3)	☐	No Defined Ditch (6)	☒	Other (9) Beach

Diagram:

Make a sketch of the culvert/structure crossing and indicate at least the following items:

- ☑ Road/street name
- ☑ Travel direction and distance from Station 0.0
- ☑ Culvert identification number
- ☑ Flow direction(s) upstream and downstream side
- ☑ Landmarks (driveways and street address, road crossings, sewer manholes, etc...)
- ☑ Driveway culverts (indicate location, material, and diameter)
- ☐ Nearby culverts crossing road/street (use culvert identification number)
- ☐ Wetlands and/or areas with ponded water
- ☐ Condition of roadside ditches
- ☐ Location of slope breaks (i.e., where flow direction changes) in roadside ditches and approximate distance from slope breaks to culvert.



Appendix B: Lummi Storm Water Facilities Summary Information

ID Number	Street Name	Culvert No	Culvert size	Comments
1	Haxton Way	1	18	Drains west, crosses to north of Slater in Slater#17, back south in Slat#18
2	Haxton Way	2	18	None
3	Haxton Way	3	0	Bridge over Lummi River
4	Haxton Way	4	36	Flat water in ditches, flow direction estimated
5	Haxton Way	5	18	Drains ditchline north of LSR, discharges to slough draining HaxtonWay #8
6	Haxton Way	6	36	Ditch invert below culvert invert
7	Haxton Way	7	36	Ditch invert below culvert inlet
8	Haxton Way	8	48	Receives flow from Kwina #1and Lummi Shore Road #2, flows to Lummi Bay
9	Haxton Way	9	12	Wetland to west contributes flow to outlet Roadside Ditch
10	Haxton Way	10	12	Wetland to west contributes flow to outlet Roadside Ditch
11	Haxton Way	11	12	Outlet ditch drains to wetland/floodplain north of Planning Office via 24"
12	Haxton Way	12	18	Drains in ditchline to floodplain and waterway near Kwina#2
13	Haxton Way	13	18	Drains to stream channel; blocked during waterline construction (Fall 1996)
14	Haxton Way	14	18	Drains to area of ponded water, culvert end broken off
15	Haxton Way	15	36	Stream drains area by Scott Road, Discharges to beach near Seaponds Rd
16	Haxton Way	16	24	Discharges to Robertson Rd #1
17	Haxton Way	17	12	Wet areas at inlet and outlet, standing water in both ditches
18	Haxton Way	18	12	Believed to discharge to beach via Robertson#2
19	Haxton Way	19	18	Nearest to Sludge Site. Believed to discharge to beach via Robertson#3
20	Haxton Way	20	18	Discharges to Sunset Way#1 then to Cagey Rd#3
21	Haxton Way	21	18	Discharges to Sunset Way#1 then to Cagey Rd#3
22	Haxton Way	22	12	Ponded area at outlet, stagnant water, no ditch or stream draining outlet
23	Haxton Way	23	18	Berm in ditch just below inlet, Discharges to beach via 8" GALV driveway
24	Haxton Way	24	18	Drains McKenzie Housing (Eagle Rd), 18" PVC, Discharges to beach in 24" PV
25	Haxton Way	25	24	24" PVC, Joined by 18" PVC from #24, Discharges to beach (24"PVC),tide ga
26	Lummi Shore Road	2	60	Outflow direction is to Haxton Way#8; discharge to Lummi Bay via Kwina#2
27	Lummi Shore Road	3	18	Drains to thick brush and wetland, inlet is residential ditch
28	Lummi Shore Road	4	12	Drains to Culvert #4 on Marine Drive, inlet ditch along south of church
29	Lummi Shore Road	5	12	Drains wetland/standing water; discharges to wetland
30	Lummi Shore Road	6	18	Discharges to wetland area
31	Lummi Shore Road	7	36	Receives flow from Culverts #1 & #2 on Scott Rd
32	Lummi Shore Road	8	18	Discharges to wetland area
33	Lummi Shore Road	9	18	Discharges to wetland area
34	Lummi Shore Road	10	12	Receives water from wetland area/ponded water; discharges to wetland area
35	Lummi Shore Road	11	18	Discharges to wetland area; tide gate at outlet
36	Lummi Shore Road	12	18	Discharges to wetland area
37	Lummi Shore Road	13	24	Inlet T/G; Outlet GALV, Discharges to beach
38	Lummi Shore Road	14	24	Discharges to beach, drains wetland overflow north of gravel road
39	Lummi Shore Road	15	18	Discharges to beach,outfall combines with stream draining Lummi Shore Rd#14
40	Lummi Shore Road	16	24	Discharges to beach, drains Cagey#9, Lightening Bird Lane#1,& So. of LSR#15
41	Lummi Shore Road	17	24	Discharges to beach, probably includes flow from Cagey#8
42	Lummi Shore Road	18	24	Discharges to beach, flow from KB#2, probably includes flow from Cagey#7
43	Lummi Shore Road	19	48	Discharges to beach, probably includes flow from Cagey#5 and Cagey#6, KB#
44	Lummi Shore Road	20	24	Discharges to beach, includes flow from Smokehouse#1 and Smokehouse#2

ID Number	Street Name	Culvert No	Culvert size	Comments
45	Lummi Shore Road	21	24	Discharges to beach, includes flow from Smokehouse#3, #4, #6, and #7
46	Lummi Shore Road	22	24	Discharges to beach
47	Lummi Shore Road	23	24	Discharges to beach
48	Lummi Shore Road	24	24	Discharges to beach
49	Lummi Shore Road	25	24	Discharges to beach
50	Lummi Shore Road	26	24	Discharges to beach
51	Lummi Shore Road	27	18	Discharges to beach
52	Lummi Shore Road	28	24	Discharges to beach
53	Lummi Shore Road	29	18	Discharges to beach
54	Lummi Shore Road	30	18	Discharges to beach; tide gate on inlet
55	Lummi Shore Road	31	12	Discharges to beach, via 12" T/G; water not flowing
56	Lummi Shore Road	32	18	Discharges to beach; via 18" T/G; water not flowing
57	Lummi Shore Road	33	18	Discharges to beach; via 18" GALV
58	Lummi Shore Road	34	12	Discharges to beach; via 12" T/G
59	Lummi Shore Road	35	18	Discharges to beach
60	Lummi View Drive	1	12	Discharges to ditch then to beach through 12" GALV
61	Lummi View Drive	2	12	Outlet not located, discharges to beach via ditch
62	Lummi View Drive	3	12	Discharges to beach, gully at outlet
63	Lummi View Drive	4	18	Discharges to beach, drains new McKenzie housing, McKenzie#1, and wetland
64	Lummi View Drive	5	12	Could not locate inlet; outlet discharges to ponded area, no outlet
65	Lummi View Drive	6	12	Discharges to beach, from C/B #1 on Lena Rd.
66	Lena Road	1	12	Discharges to beach via 12" GALV and Lummi View Drive#6
67	Emma Road	1	12	Discharges to beach; via 12" PVC
68	McKenzie Road	1	12	Drains McKenzie housing waterline road, Discharges to Lummi View Dr#4
69	Leeward Place	1	12	Discharges to beach (apparently - outlet on private property)
70	Leeward Way	1	12	Inlet and outlet not found; believed to discharge to beach
71	Boynton Road	1	18	None
72	Boynton Road	2	12	Discharges to Robertson Road#1
73	Robertson Road	1	30	Discharges to beach/Lummi Bay
74	Robertson Road	2	15	Discharges to beach via 12" T/G
75	Robertson Road	3	24	Discharges to beach/Lummi Bay
76	Harnden Road	1	12	Discharges to beach via ditch and channel just north of Harnden Rd.
77	Harnden Road	2	12	Discharges to beach via ditch and channel just north of Harnden Rd.
78	Smokehouse Road	1	18	D/S end covered by gravel, discharges to Lummi Shore Road #20
79	Smokehouse Road	2	18	Discharges to Lummi Shore Road #20
80	Smokehouse Road	3	18	Drains area near Kinley Way, Discharges to B. Bay via Lummi Shore Road#21
81	Smokehouse Road	4	18	Large area of ponded water near inlet & outlet
82	Smokehouse Road	5	8	Non-functional; Inlet above ditch, outlet buried
83	Smokehouse Road	6	18	Outlet ditch discharges to stream from Culvert #3
84	Smokehouse Road	7	18	Discharges via roadside ditch to stream at outlet of Smokehouse#3
85	Smokehouse Road	8	18	Likely drains toward Lummi Shore Road#27-#30
86	Smokehouse Road	9	24	Ponded water west of inlet and outlet
87	Smokehouse Road	10	24	Wetland area around inlet and outlet
88	Smokehouse Road	11	24	Large wetland area around inlet and outlet

ID Number	Street Name	Culvert No	Culvert size	Comments
89	Smokehouse Road	12	24	Outlet drains north along Haxton Way; crosses at Haxton Way#23
90	Kinley Way	1	12	Kinley Way flow via gutter/curb to C/Bs, 12" T/G cross to Smokehouse#7,6,3
91	Cagey Road	1	12	Drains to Cagey#3 via Sunset Way#1
92	Cagey Road	2	12	Drains to Cagey#1
93	Cagey Road	3	24	Discharges to beach just south of beach access road.
94	Cagey Road	4	18	Outlet to roadside ditch along Haxton Way, flows to beach via Haxton Way#19
95	Cagey Road	5	18	Inlet 18" ADS, small outlet stream flows south
96	Cagey Road	6	12	Drains housing in Zeta Place (perimeter ditch is source of most of flow)
97	Cagey Road	7	18	Drains large wetland area north of Cagey and east of Chief Martin Rd.
98	Cagey Road	8	12	Drains area near Tony's Auto Wrecking
99	Cagey Road	9	12	Discharges to Lummi Shore Road #16
100	Sunset Way	1	24	Discharges to Cagey Road#3
101	Lightening Bird Lane	1	24	Discharges to Lummi Shore Road#16
102	Chief Martin Road	1	12	Contributes flow to Kwina#1, more flow along west side of Chief Martin
103	Chief Martin Road	2	12	Culvert in roadside ditch along west side of Chief Martin Road
104	Chief Martin Road	3	12	Culvert in roadside ditch along west side of road; flows to Chief Martin#2
105	Chief Martin Road	4	18	Drains west part of Scott Road too, contributes to flow at Chief Martin #5
106	Chief Martin Road	5	12	Drains to Lummi Bay via Haxton Way#15
107	Chief Martin Road	6	12	Culvert in ditch along west side of Chief Martin Road
108	Chief Martin Road	7	24	Small streams around culvert inlet drain wetland to east of Chief Martin Rd
109	Chief Martin Road	8	12	Drains to Cagey Road#7
110	Scott Road	1	18	Drains to Scott Road#2, small stream near outlet also contributes flow
111	Scott Road	2	24	Drains to Kwina Slough via Lummi Shore Road#7
112	Kwina Road	1	36	Drains via ditchline around pasture eastern perimeter to Haxton Way#8
113	Kwina Road	2	84	Flow in both directions (tidal influence), box culvert 3ft x 6ft inside
114	Kwina Road	3	24	Submerged, flow may be in both directions (tidal influence)
115	Hillaire Road	1	18	Submerged, flow may be in both directions (tidal influence)
116	Hillaire Road	2	18	Submerged, flow may be in both directions (tidal influence)
117	Hillaire Road	3	0	Bridge over Lummi River, levee on both sides
118	South Red River Road	1	18	Discharges to Beach via Lummi River, suspended pipeline (pumped)
119	South Red River Road	2	24	Discharges to Beach via Lummi River, lower elevation than SRRR#1, tide gate
120	Ferndale Road	1	12	Ponded area near outlet, stagnant water
121	Ferndale Road	2	24	~85% of flow from ditch that originates near Slater #3,#4
122	Ferndale Road	3	24	Discharges to Slater Slough
123	Ferndale Road	4	18	Discharges to Slater Slough via ditchline
124	Ferndale Road	5	0	Bridge over Kwina Slough, levee on north side of slough only
125	Rayhorst Road	1	24	Only culvert on Rayhorst Road, flows to Ferndale Road#3
126	Marine Drive	1	18	Submerged, flow may be in both directions, diameter estimated
127	Marine Drive	2	0	Bridge over Kwina Slough
128	Marine Drive	3	18	Submerged, south end blocked?, flow in both directions?, diameter estimated
129	Marine Drive	4	12	Both ends could not be located, water flows through, discharges to wetland
130	Slater Road	1	48	Outlet to north, ditch at outlet also drains fields to north
131	Slater Road	2	48	Drains to north side of Slater Rd, paired with Slater#1
132	Slater Road	3	48	Ag. ditch at outlet drains to Ferndale Road#6 & #2

ID Number	Street Name	Culvert No	Culvert size	Comments
133	Slater Road	4	48	Paired with Slater#3, Drains via Ag. Ditch to Ferndale Road#6 & #2
134	Slater Road	5	24	Ponded areas at inlet and outlet, no ditches
135	Slater Road	6	18	Buried outlet, stagnant water at inlet
136	Slater Road	7	60	Inlet and outlet Ag. ditches ~240 ft east of culvert
137	Slater Road	8	60	Inlet and outlet Ag. ditches ~240 ft east of culvert
138	Slater Road	9	60	In tandem with culverts Slater#7 and Slater#8
139	Slater Road	10	36	U/S end buried, non-functional culvert
140	Slater Road	11	0	Bridge over Lummi River
141	Slater Road	12	84	Box culvert, Discharges to Beach via Lummi R., pipe w/ tide gate at levee
142	Slater Road	13	30	Ponded water at inlet and outlet, no ditches
143	Slater Road	14	30	Drains fields to south, flows to ag. ditchline along north side of Slater
144	Slater Road	15	84	Schell Ditch crossing, drains to Lummi River
145	Slater Road	16	18	Drains to south, then to Slater#17 via Haxton Way#1
146	Slater Road	17	24	Drains to north, flows to west, crosses back southward at Slater#18
147	Slater Road	18	42	Ag. Ditch ~210 ft west flows to inlet, drains to Jordan Creek
148	Slater Road	19	24	Discharges to wetland area to south
149	Slater Road	20	36	Inlet stream ~180 ft west, pond; outlet appears to drain to Jordan Creek
150	Slater Road	21	24	A little more flow than Slater#20, source is ditch near Slater#22
151	Slater Road	22	18	Water ponds at outlet, most of water for #21 from ditch ~25 ft east of #22
152	Slater Road	23	18	Ponded water on both sides of culvert
153	Slater Road	24	120	East branch of Jordan Creek (approx. dimensions 8.7' tall, 12.2 ' wide)
154	Slater Road	25	24	West branch of Jordan Creek
155	Slater Road	26	12	Drains to near outlet of Slater#25, ~95% of flow in north ditch flows to#26
156	Slater Road	27	18	Drains toward north side
157	Slater Road	28	18	18" B/S drains roadway near traffic island
158	Slater Road	29	30	Gate w/ apparent filter on 24" ADS that flows to inlet from TOSCO property
159	Slater Road	30	30	In tandem with Slater #29
160	Slater Road	31	24	Drains to southside of Slater then to east to Slater#29,#30 outlet stream
161	Slater Road	32	18	~60% of flow in inlet RDitch continues toward Slater#33
162	Slater Road	33	18	Large areas of ponded water on both sides of road adjacent to RDitches
163	Slater Road	34	24	Ditch network drains field in TOSCO property, outlet flows to creek at #35
164	Slater Road	35	24	~95% of water in stream comes from Slater#33 & #34 area
165	North Red River Road	1	120	Jordan Creek, flows to cutoff Lummi R. Distributary (Dimensions 9.5'x13.5')
166	North Red River Road	2	72	Possibly for flood relief only, no inflow ditch or channel found
167	North Red River Road	3	24	Stream contributing ~85% of flow ~180 ft west
168	North Red River Road	4	12	Outlet discharges to hillslope
169	North Red River Road	5	18	Small stream ~25 ft west contributes ~25% of flow, outlet is gully
170	North Red River Road	6	18	Drains to Shaw Court then to golf course
171	North Red River Road	7	18	Flows toward outlet of No. Red River Road#6
172	North Red River Road (now Lake Terrell Road	8	18	Wetlands on both sides, flow is toward the west
173	North Red River Road (now Lake Terrell Road	9	18	18" B/S flows westward along Slater Road, overflow is in 12" B/S to NRRR.
174	Waldron Drive	1	12	Receives flow from Lake Terrell Rd & NE part of Orcas Way
175	Decatur Drive	2	12	Ponded water at inlet, contributes flow to SPH culverts #6, #8, and #9
176	Prevost Way	3	12	C/B at outlet; contributes flow to SPH #16, #14, and #12

ID Number	Street Name	Culvert No	Culvert size	Comments
177	Prevost Way	4	12	Contributes flow to SPH #16, #14, and #12
178	Prevost Way	5	12	Contributes flow to SPH #10 and #12
179	Saanich Avenue	6	12	Contributes flow to SPH #8, #9, and #11
180	Lopez Drive	7	12	Contributes flow to SPH #8, #9, #11. Drains inner loop of Lopez/Pender Dr.
181	Pender Drive	8	12	Contributes flow to SPH #9, #11.
182	Orcas Way	9	12	Contributes flow to SPH #11
183	Decatur Drive	10	12	Contributes flow to SPH #12
184	Decatur Drive	11	12	Discharges to Beach, drains W. side Lk Terrell Rd and SPH NE of Pender Dr
185	Sinclair Drive	12	18	Discharges to Beach via a 12" GALV, Drains SPH west of Pender Drive
186	Moresby Way	13	12	Contributes flow to SPH #12
187	Cyprus Way	14	12	Contributes flow to SPH #12
188	Cyprus Way	15	18	Discharges to a 12"GALV that flows to SPH #12
189	Moresby Way	16	12	Contributes flow to SPH #14 and #12
190	Waldron Drive	17	12	Contributes flow to N. Red River Road #7
191	Waldron Drive	18	12	Ponded water to west of outlet, overflow to wooded area
192	Waldron Drive	19	12	Contributes flow to SPH #18, water on roadway due to blocked driveway culv
193	Guemes Way	20	12	Contributes flow to N.Red River Road #5
194	Shaw Court	21	12	Drains to Shaw Court outlet at SE end of Shaw Ct; flow goes to golf course
195	Beach Way	1	12	Drains to pasture land, may contribute some flow to Sucia Drive#1
196	Sucia Drive	1	36	Discharges to Beach, C/B at 4780 Sucia also contributes flow
197	Sucia Drive	2	12	Discharges to Beach, wetland at inlet, broken tide gate, 18" GALV outlet
198	Sucia Drive	3	12	Discharges to wetland area via 12" ADS, water ponds at C/B
199	Sucia Drive	4	12	Discharges to wetland area via 12" ADS
200	Maple Lane	1	12	12" PVC connects Maple Lane C/Bs #1 and #2
201	Maple Lane	2	12	12" PVC connects Maple Lane C/Bs #1-3
202	Maple Lane	3	12	12" ADS connects Maple Lane C/B #3 to #4
203	Maple Lane	4	18	Discharges to beach in 18" PVC, flow from Maple Lane C/Bs #1-5.
204	Maple Lane	5	12	Contributes flow to Maple Lane C/B #4, flow over Georgian Dr-no ditch
205	Olympic Drive	1	10	Flows to wetland
206	Germain Road	1	12	Contributes flow to Neptune Circle#1
207	Neptune Circle	1	18	Discharges to hillslope at SW corner of Neptune Circle
208	Neptune Circle	2	12	Depression/ponded area at outlet
209	Beach Lane	1	12	Outlet ditch flows to field at base of hill (may continue to Sucia Dr #1)
210	Cobble Way	1	12	Contributes flow to Beach Lane#1
211	Stuart Circle	1	12	Flow direction could not be determined
212	Stuart Circle	2	12	Flow direction could not be determined
213	Salt Spring Drive	1	12	Discharges to 12" GALV that discharges to beach (Onion Bay)
214	Salt Spring Drive	2	18	Drains lake via box inlet, tide gate, discharges to beach via 18" T/G
215	Salt Spring Drive	3	12	Discharges to beach via tide gate and 12" T/G
216	Dike Road	1	24	Receives flow from Haxton and Haxton#12, discharges to outlet of Kwina#2
217	Dike Road	2	18	Inlet receives flow from curb/gutter & rocked drain, ponded area at outlet
218	Dike Road	3	18	Drains south end of Ti'opi' Loop, fed by ditchline and French drain
219	Dike Road	4	12	On gravel road (private)
220	Dike Road	5	12	Drains 4-5 houses at end of Dike Road (Nick Kinley's)

ID Number	Street Name	Culvert No	Culvert size	Comments
221	Harbor Lane	1	24	Drains to KB#2 which drains to beach via LSR #18
222	Bayview Drive	2	24	Most of flow from KB#1, Discharges to LSR#18
223	Harbor Place	3	12	Drains to KB#2 then to beach via LSR#18
224	Bay Place	4	18	Drains to KB#1, then to KB#2, then to beach via LSR#18
225	Kel Bay Avenue	5	12	Flow from Cagey#6 & #7 (2/3 to KB#5, 1/3 to KB#6), discharge to KB#4, #1,
226	Kel Bay Avenue	6	12	Drains via KB#7 then to beach via LSR#19.
227	Bayshore Drive	7	18	Receives flow from KB#6 and wet area between Bayshore Dr. & Shorewood La
228	Shorewood Lane	8	12	Roadside ditch along LSR, drains to LSR#18
229	Postal Avenue	1	18	Drains entire west side of Postal Ave., Discharges to LSR#34
230	Kwina Slough Levee	1	48	Discharges to Beach via Kwina Slough & tidegate - beaver dams alter flow
231	South Road on Levee (seawall)	1	48	Discharges to Beach at NW corner of Seaponds dike, tidegates non-functional
232	North Road on Levee (seawall)	1	0	Discharges to Beach near golf course, Approx. 8ft wide, 6ft deep, tide gate
233	Ferndale Road	6	18	Receives flow from Slater#3 & #4
234	Ferndale Road	7	18	Inlet face covered with dirt, some seepage through as trickle at outlet
235	North Road on Levee	2	0	Discharges to Beach, Approx. 5 ft wide 5.25 ft deep, tide gate
236	North Road on Levee	3	0	Discharges to Beach, Approx. 5 ft wide, 5.25 ft deep, tide gate
237	South Road on Levee	2	48	Discharges to Beach, Non-functioning tide gate, #2 of 6 culverts.
238	South Road on Levee	3	48	Discharges to Beach, Non-functioning tide gate, #3 of 6 culverts.
239	South Road on Levee	4	48	Discharges to Beach, Non-functioning tide gate, six other culverts
240	South Road on Levee	5	48	Discharges to Beach, Non-functioning tide gate, 1 of 6 culverts.
241	South Road on Levee	6	48	Discharges to Beach, Non-functioning tide gates, southern 1 of 6 culverts.
242	Southern Access Road to South Road on Lev	1	42	See maps, discharges to 6 culverts along south levee road with tidegates
243	Southern Access Road to South Road on Lev	2	42	See map,2 of 4 culverts on access road near 6 culverts on South Levee Road.
244	Southern Access Road to South Road on Lev	3	42	3 of 4 culverts near the 6 culverts on South Levee Rd; access by blockhouse
245	Southern Access Road to South Road on Lev	4	42	4 of 4 culverts, access via southern fork of block house road.
246	Northern Access Road to South Road on Lev	1	42	See map, discharges to 6 culverts on S. Levee Road.